Re-inventing Architecture with Text-to-image Generative AI

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Cover photo credit : by author, on midjourney
Prompt used : “Futuristic Architecture Building, Blurred with Blue and purple Light, Cover of a Book, Dark composition, Artificial intelligence X Architecture Theme”

MEMOIRE OF ARCHITECTURE

Re-inventing Architecture with Text-to-image Generative AI

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How can architects use text-to-image AI to increase creativity and improve the design?

Keywords

artificial intelligence - architecture - design process - space perception - human decision-making - spatial data - big data - machine learning - deep learning - neural network - predictability - diffusion model - algorithm - prompt engineeringh - feasibility of a project

Abstract

Artificial intelligence is drastically enhancing the capabilities of architects in the design. This paper explores the interaction of Architecture and Artificial Intelligence in the age of Big Data. This research explores the integration of text-to-image AI, a machine learning model that generates composed images constructed from a dataset based on written prompt, in architectural design, addressing the overarching question: How can architects use text-to-image AI to increase creativity and improve design? The study investigates the potential of AI algorithms to enhance creativity, efficiency, and sustainability in architectural creations. It focuses on the use of generative AI for design optimization, preventing issues through AI integration in the pre-design phase, and evaluating the flaws in AI outputs. It also investigates the use of generative AI to efficiently consider various options. Findings underscore the crucial role of architects in decision-making and the importance of learning prompt writing. The study contributes practical methodologies for architects to optimize their use of AI tools, providing valuable insights into the evolving landscape of AI in architectural design.

The research will first address the state of the art of Architectural Artificial Intelligence by first going through the chronology of sequences that lead to the introduction of Artificial Intelligence in the Architecture world. Then, AI systems will be briefly explained to understand the algorithm behind text-to-image AI. The second part of this research is experimental. It includes a set of tests conducted on different text-to-image AI in order to assess the flaws in the output and learn the prompt writing process. Thirdly, the article explores potential data sources for architects in order to identify parameters of architecture that make efficient design. And then finally, find functions architects wish to delegate to their new smart assistant : Artificial Intelligence. The final part of this research is an open discussion of the future of Architectural conception and the possibilities of including Artificial Intelligence as a tool in the Architectural practice and academic world.

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Lastly, I pay tribute to those whose stories are intertwined with mine, especially those no longer with us; their memory lives on within these pages.

This research paper belongs to each of you who have played a part in my life. Thank you for your contributions, belief in the power of storytelling, and for being an integral part of this narrative.

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1 | State of The Art of Architectural Artificial Intelligence

1.1 Introduction of Artificial Intelligence in Architecture

Over the past few decades, Artificial Intelligence has been gradually introduced in the Architecture profession through the development of several software tools and technologies that use AI algorithms to enhance the Architectural design. AI is a technology that is becoming more and more abundant in the field of Architecture, assisting architects in creating designs that are more effective, efficient, and sustainable.

1.1.1 Chronology and Sequences

The Architectural process and the methods of conception were always at the core of the debate among architects. New practices kept emerging as technology made an appearance in almost all disciplines. In the last few months, there has been a boom in AI news, from the announcement of midjourney (a text-to-image AI) to ChatGPT (an AI chatbot). Note that the growth of AI has been gradual, rather than a disruption in events, there is a continuity that led Architecture through various evolutions until this day. There are five main steps in the evolution of Architecture conception with technology beyond the historical background (shown in figure 1).

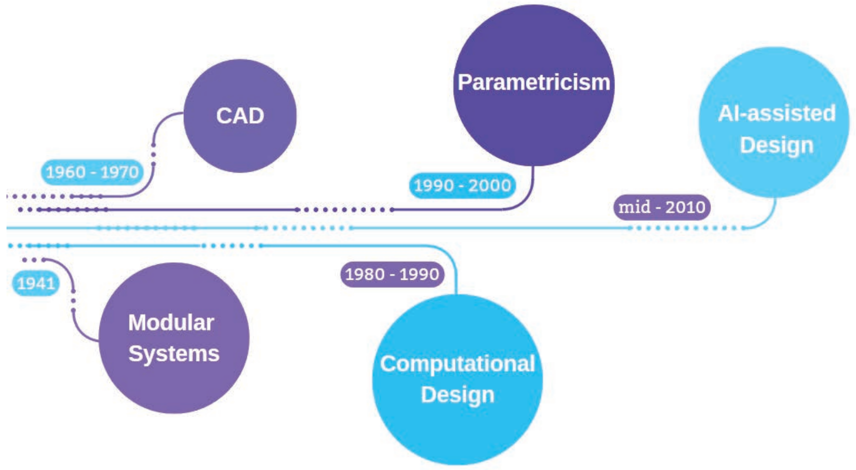

Figure 1: Chronology of The Sequences That Lead to AI-assisted Design (Souce: Author)

Architectural design is traced back to ancient times when human beings started to create shelter from any element they could find. With time, architects started implementing systems of structure in the design process : Modular systems[1]. Introduced by Gropius, the system raised a lot of questions by practitioners; it was a game changer that insulated some simplicity in the technical and financial aspect. Modular systems gave a basis for later technologies, it created repetitions, specific dimensions and logic to Architectural conception.

After the transition into modules in the 1960s and 1970s, architects began to use basic computer-aided design (CAD) software to create a digitized version of their designs. These early tools allowed architects to create 2D drawings and simple 3D models of their designs.
This first tool made it possible to make small changes in the design without having to redraw the whole elements (plans,

1 Walter Gropius, Konrad Wachsmann, “Theory and Experiment. In The Dream of the Factory-Made House”. https://doi.org/10.1162/a8667414.209f27d1

sections, elevations). It made the Architecture process time-optimized.

The use of CAD led to further reflections on the approach to the Architectural project. In the 1980s and 1990s, architects started using more advanced CAD software, which could perform calculations and simulations. It allowed them to analyze their ongoing projects in early stages and collect data, testing the structure, energy efficiency, sun exposure, ventilation, etc. A new area of study called Computational Design will be developed by the next generation of computer scientists and architects, the main mission is :

“investigating how machines can enhance the creative process, and more specifically, the architectural production as a whole[2]”

Computational design involves the use of computer algorithms and parametric modeling to generate and manipulate architectural forms. It allows control over the geometry and makes the design more reliable in terms of cost and feasibility. Greg Lynn has been a prominent figure in advancing the integration of computational tools into the design process : Computational design enables architects to create designs that respond to various factors, including environmental conditions, user behavior, or programmatic requirements. This responsive aspect is evident in Lynn’s work, where the design is not static but adaptable and dynamic[3].

However, as designers worked with Computational Design, a few issues finally surfaced. Particularly, the repetitive nature of certain tasks and the inability to manipulate complex geometric shapes became major obstacles. These opened the door for a brand-new trend in the field of Computational Design called Parametricism.

In the late 1990s and early 2000s architects started to use Parametric Design tools.

2 Stanislas Chaillou, “AI & Architecture, Towards a New Approach,” Stanislas Chaillou | Architecture | Technology, 13, Accessed April 23, 2023, http://stanislaschaillou.com/articles.html#pub-3-tag.
3 Lynn, Greg. Animate form. New York: Princeton Architectural Press, 1999. p.1-11

“Parametric Design is the process of designing in environment where design variations are effortless, thus replacing singularity with multiplicity in the design process[4]”

It allowed them to build designs that could be modified and adjusted depending on a set of rules and parameters. Instead of manually implementing inputs (certain defined parameters) which is time consuming, Parametric design allows the architects to manipulate pre-defined key parameters. This lets the architect communicate data and experiment with different shapes, geometries, and potential scenarios. An example of the parametrization of Architecture is the work of Zaha Hadid, with the use of Grasshopper, she was able to have unprecedented control over her building’s geometry through a set of parameters. After Grasshopper, the development of BIM (Building Information Modeling) led to a step further into the parametrization of design.
There is a common theme among them all:

“the explicit use of parameters as the inspiration for design[5]”

However with the use of parametric tools, there are few subjects that opened discussions and led to the search for more advanced tools. Parametric design has shown to ignore the enormous complexity of space planning. It doesn’t take into account several parameters and significant cultural and socioeconomic aspects. Although Parametric design gave architects a set of tools to make the design process more elaborate in terms of studies conducted (environmental, ventilation, etc.) and faster in terms of making changes to the geometry of the design, it still has room for amelioration as with any technology or evolution.

This need for more defined results led to the exploration of Artificial Intelligence in the field of Architecture. Design is hard to define. Through-out history, there are a lot of approaches to design as well as different parameters to be considered. As architects, we know that every project goes through several initial layouts and options and a research/learning phase. Which leads to the introduction of the last

4 Barrios Hernandez, Carlos Roberto, “Thinking parametric design: introducing parametric Gaudi, in: design Studies, Vol. 27, 2006, p 310
5 Stanislas Chaillou, “AI & Architecture, Towards a New Approach,” Stanislas Chaillou | Architecture | Technology, 10, Accessed April 23, 2023, http://stanislaschaillou.com/articles.html#pub-3-tag.

step, AI-assisted Design or Generative Design[6]. The intention behind this new way to approach the design process is to use computing algorithms to :

1. Generate several options
2. Take in the input of the user
(more defined parameters and constraints)
3. Create optimized solutions

Design professionals can explore a far wider range of design options with Generative Design in a lot less time than with traditional design techniques.

The Precursors

Early on, a few theorists explored Artificial Intelligence in the Architecture field. It started with the idea of a "machine assistant" which would assist the architect by adapting room layouts for example. We can think of URBAN V[7] by Negoponte, an early AI system distinguished by two layers of information : one deduced by the machine and the other one set by the user. It translates the complementary relationship between human beings and machines. A few years later, Cedric Price, who was the architecture chair professor at Cambridge University, created the GENERATOR[8] (1976). Recognizing Negroponte[9]'s work, Price expanded on the work on AI by exploring the concept of autonomous, constantly changing buildings that will "intelligently" respond to and adapt to users' behavior.

The Sequences of the Emergence of Artificial Intelligence

The first AI or machine assistant developed by Negopronte and soon after Cedric Price did help with learning about the limits of the initial algorithms and how architects wanted these machines to interfere as assistants.

Not long after that, in the 80s, there was yet again an interest in Artificial Intelligence. There was a sudden increase in computational potential, mainly in Network and Machine Learning.

6 "What is Generative Design | Tools Software | Autodesk." Autodesk | 3D Design, Engineering & Construction Software. Accessed June 4, 2023. https://www.autodesk.com/solutions/generative-design.
7 "URBAN 5's Abstractions." MIT Press Open Architecture and Urban Studies. Accessed May 4, 2023. https://mitp-arch.mitpress.mit.edu/pub/m27d3vdh/release/1.
8 Furtado C. L., Gonalo M. "Cedric Price's Generator and the Frazers' systems research." Technoetic Arts 6, no. 1 (May 28, 2008): p.55–72. https://doi.org/10.1386/tear.6.1.55_1.

There are two key revolutions : Inference engines and expert systems.

An inference[10] engine is a software component that applies logical rules and knowledge to a set of facts or data to derive new information or make decisions. It is commonly used in expert systems, which are computer programs that simulate the decision-making ability of a human expert in a specific domain by using a knowledge base and rules.
At the time it was a breakthrough in the world of Artificial Intelligence.

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Expert systems[11] consist of three main components :
1. The knowledge base, which contains the facts and the rules
2. The inference engine, which applies the rules to the facts
3. The user interface, which allows the user to interact with the system and provide input

Expert systems can be used to deliver reliable and consistent advice or answers, automate repetitive and routine decision-making processes, and lower human error. They can, however, have shortcomings, such as the requirement for intensive knowledge engineering to create and maintain the knowledge base and the incapacity to manage challenging or ambiguous circumstances that might call for human judgment and reasoning.

After the widespread use of expert systems in the 1980s, there was the emergence of GANs in the mid-2010s.

9 Negroponte, Nicholas. Soft architecture machines. Cambridge, Mass: The MIT Press, 1975.
10 "Chapter 43 - Artificial Intelligence: Expert and Knowledge Based Systems." In Data Handling in Science and Technology. Vol. 20, p 627–647. 1998. https://doi.org/10.1016/S0922-3487(98)80053-1.
11 *Ibid*

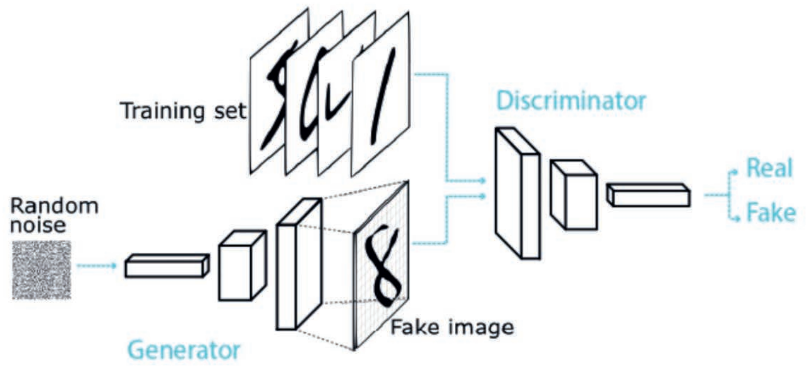

Figure 2: Diagram of a GANs System[12]

Generative Adversarial Networks (GANs) are a somewhat recent development in the field of Artificial Intelligence and Machine Learning (shown in figure 2). GANs was first introduced in 2014 By Ian Goodfellow and colleagues in a paper. Their suggested method involved simultaneously training two neural networks, a generator and a discriminator, to produce new data that roughly corresponded to a training set. The way it works is :

- The generator learns to generate new data
- The discriminator learns to distinguish between the real data and the generated data

With GANs systems, there was a success in the generation of high-quality images. As well, this has led to a widespread interest and research in the field. The success of GANs in generating high-quality images and other types of data has led to widespread interest and research in the field, and GANs are now used in a wide range of applications, such as image and video generation and natural language processing. In the field of machine learning the transition from GANs AI to text-to-image AI was a natural evolution. As mentioned earlier, GANs was first introduced in 2014, however, it wasn't until 2016 that the first text-to-image generation model appeared called StackGAN[13], proposed by Scott Reed and colleagues.

StackGAN created images from word descriptions using a two-stage process. A GAN was used in the first stage to create a low-resolution image from the text prompt, and another GAN was used in the second stage to create a high-resolution image from the low-resolution image. With this method, the generated images were of higher quality and the prompts could be more precise.

Since then, a number of different text-to-image models have been proposed. In 2017, the Transformer, a machine learning architecture is introduced in the paper "Attention is All You Need[14]." It revolutionized natural language processing by using self-attention mechanisms to efficiently capture dependencies between input elements, enabling parallelization and improving performance in tasks like machine translation and text generation. And then, released in 2018, AttnGAN[15] (Attentional Generative Adversial Network), includes a focus system that focuses on particular features mentioned in the text. These models have produced remarkable results in producing high-quality images from prompts and have a wide range of possible applications in fields like architecture.

However, before getting into text-to-image AI and how they really work, it's important to understand the different AI systems that exist and the ones that have potential for the Architecture profession later on.

1.1.2 What are the Different AI Systems

Artificial intelligence started with the idea of creating a human-like thinking system.

They are trained to perform tasks that would normally require human intelligence such as decision-making, detecting objects in images, or even creating lifelike conversations in a chat box.

AI systems are very diverse and exist in different stages and types. It is important to understand that AI systems are constantly changing and evolving. Therefore, most advanced AI stages and types exist only in theory. To get a better understanding of this research, AI systems will be briefly explained in the first section below.

Stages of Artificial Intelligence

Artificial Intelligence has three stages (shown below in

12 "15 Generative Adversarial Networks (GAN) Based Project Ideas." ProjectPro. Accessed June 4, 2023. https://www.projectpro.io/article/generative-adversarial-networks-gan-based-projects-to-work-on/530.
13 Reed, Scott, Zeynep Akata, Xinchen Yan, Lajanugen Logeswaran, Honglak Lee, and Bernt Schiele. "Generative Adversarial Text to Image Synthesis." p. 1–10. https://arxiv.org/pdf/1605.05396v2.pdf.
14 Vaswani, Ashish, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Lukasz Kaiser, and Illia Polosukhin. "Attention is All You Need." 2017, p.1–11. https://proceedings.neurips.cc/paper_files/paper/2017/file/3f5ee243547dee91fbd053c1c4a845aa-Paper.pdf.
15 Xu, Tao, Pengchuan Zhang, Qiuyuan Huang, Han Zhang, Zhe Gan, Xiaolei Huang, and Xiaodong He. "AttnGAN: Fine-Grained Text to Image Generation with Attentional Generative Adversarial Networks." . https://arxiv.org/pdf/1711.10485.pdf.

figure 3) in scientific knowledge :

Artificial Narrow Intelligence (ANI)
Artificial General Intelligence (AGI)
Artificial Super Intelligence (ASI)

When an Artificial Intelligence system performs a set of predefined tasks, it is known as ANI. It can only perform very specific instructions preset by a defined data. Alexa and Siri are examples of ANI. There are more advanced stages of Artificial Intelligence such as AGI (Artificial General Intelligence) known as Strong AI that possesses the capacity for thought and judgment similar to that of humans. It can basically mimic human intelligence and decision-making abilities. As well, theoretically speaking, the most advanced stage of AI that doesn’t exist yet is ASI (Artificial Super Intelligence), it is defined as a system that surpasses human intelligence.[16]

Types of Artificial Intelligence

Artificial intelligence research is one of the most exciting areas of technology. There are numerous ongoing discoveries and developments, the majority of which fall into four categories (shown in figure 4): reactive machines, limited memory, theory of mind, and self-aware AI.

The development of reactive machines, the most basic type of AI, marked the beginning of AI. As it is clear from its name : Reactive machines react. They can respond to immediate requests and tasks, but they cannot store memory or learn from previous experiences. The very next step in the advancement of AI is the ability to store knowledge. This kind of AI is known as limited memory AI because it can build its own limited knowledge base and use that knowledge to advance over time. Machines with limited memory can learn from previous experiences and store knowledge, but they cannot detect subtle changes in the environment or emotional signs.The concept of AI that can comprehend and detect the emotions of others has yet to be achieved. This idea is known as the “theory of mind”.

16 O. Strelkova, and O. Pasichnyk. “THREE TYPES OF ARTIFICIAL INTELLIGENCE.” Khmelnitsky National University, n.d. Accessed October 20, 2023. p.1-4 https://eztuir.ztu.edu.ua/bitstream/handle/123456789/6479/142.pdf?sequence=1&i.

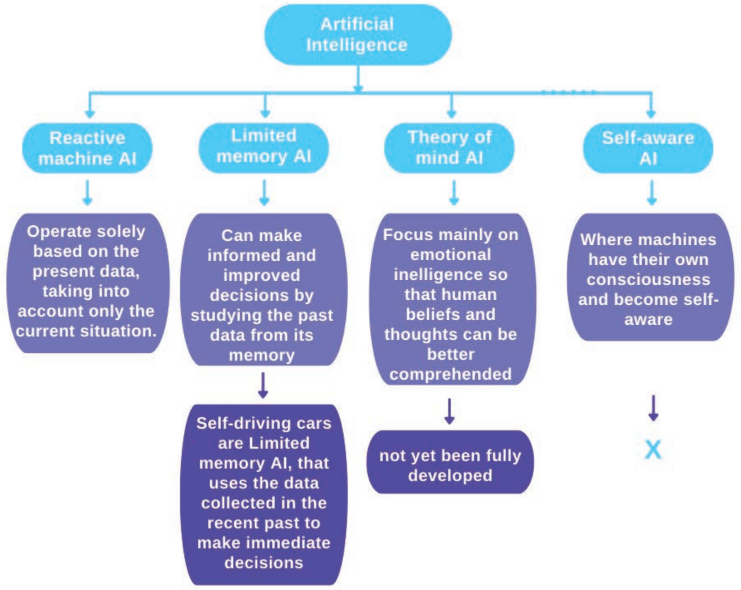

Figure 3: The Different Stages of Artificial Intelligence[17]
(Source : Author)

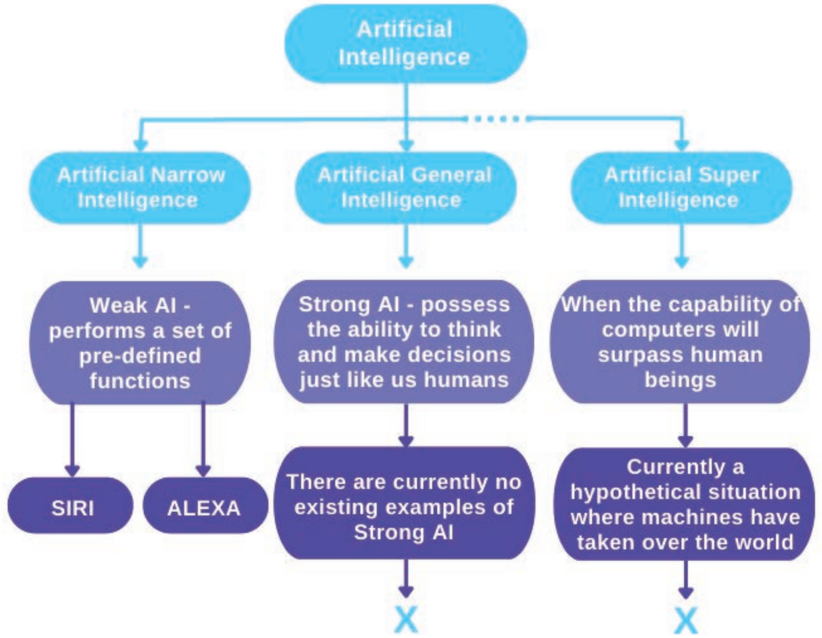

Figure 4: The 4 Different Types of Artificial Intelligence

The last stage is when Artificial Intelligence develops self awareness, AI machines will be beyond our control because they will be able to sense not only the feelings of others, but also their own[18].

In the following section, there is an exploration of a specific

17 O. Strelkova, and O. Pasichnyk. “THREE TYPES OF ARTIFICIAL INTELLIGENCE.” Khmelnitsky National University, n.d. Accessed October 20, 2023. https://eztuir.ztu.edu.ua/bitstream/handle/123456789/6479/142.pdf?sequence=1&i.
18 “What Are The Types Of Artificial Intelligence? | Branches of AI | Edureka.” Edureka. https://www.edureka.co/blog/types-of-artificial-intelligence/.

Artificial Intelligence system, an example of ANI (Artificial Narrow Intelligence) that generates high-quality images from textual description. The purpose is linking that system to the Architecture process and understanding the transformation of Architecture with that tool.

1.1.3 Artificial Intelligence : Transforming Architecture

From the initial stages of design and planning all the way through to the construction and ongoing maintenance of architectural projects, Artificial Intelligence (AI) has emerged as a transformative force with immense potential to revolutionize various aspects of the field. With its powerful analytical capabilities, AI can efficiently process and interpret vast amounts of data, enabling architects to gain valuable insights that guide their design choices, enhance building performance, and optimize costs. By using the power of AI, architects can leverage its capabilities to verify the feasibility of their designs even before they are physically realized, thanks to advanced simulations and predictive modelling.

In contemplating the integration of artificial intelligence into the future of architecture, our primary focus revolves around the critical examination of existing challenges within the field of architecture that necessitate innovative solutions. Today, new buildings need to meet higher standards for saving energy, ensuring user comfort, being environmentally friendly, and managing projects efficiently, which is the direction for future construction. To tackle these challenges, we must include methods that consider multiple factors and evaluate the overall performance in the design process. However, the tools we have for designing buildings often come up short, especially in the early planning stages, the pre-design phase, because we have limited time, information, and resources.

The pre-design phase in architecture is really important because the choices made here affect the whole construction process.[19] Sadly, these early decisions are often made without enough analysis, so architects end up using familiar solutions and delay important decisions

19 Contrada, Francesca. “L’apport de la Constructibilité au pré-design.Évaluation et support au choix des solutions techniques.” Thesis, Paris Est, p.22-28, 2019.

until later in the design. This creates problems like higher costs, worse performance, delays, and budget issues. In my research, I want to emphasize how crucial the pre-design phase is and explore how AI can help solve these problems, like reducing design costs and preventing performance issues.

For example, AI simulations can encompass a wide range of scenarios, providing architects with the ability to explore multiple design iterations and assess their impact on various factors such as structural integrity, energy efficiency, and occupant comfort. By simulating and analyzing these scenarios, architects can save significant amounts of time and resources that would have otherwise been spent on manual testing and adjustments.

In the upcoming research part, the focus will be on the exploration of several remarkable text-to-image AI systems. This investigation aims to assess the effectiveness of these recent advancements and unveil the wide-ranging possibilities they offer within the field of architecture. By thoroughly looking into these cutting-edge systems, the aim is to measure the extent to which they can reshape architectural practices and open up new avenues for innovation. Through this exploration, as architects, we will gain insights into the potential applications of text-to-image AI systems and their ability to make the design processes simpler and more efficient, enhance visualizations, and improve communication in architectural projects.

In January 2021, an advanced image generating system was developed by OpenAI[20]. The way it works is by using a neural network trained on a large dataset of images and textual descriptions. There are two main components to this neural network: A transformer and a generator. The transformer takes the textual description and transforms it into a collection of vectors that represent the text’s meaning. The generator then makes an image that corresponds to the description using these vectors.

1.1.4 Understanding the Algorithm Behind text-to-image AI

Algorithms are the basis for everything. It is a universal

20 OpenAI. “About OpenAI.” OpenAI, Accessed December 11, 2022. https://openai.com/about/.

language that you translate to a specific program. The term algorithm[21] means : a set of instructions or procedures that are designed to solve a specific problem or perform a specific task. It takes inputs and then produces outputs. The idea behind algorithms is to achieve specific goals. Algorithms are a fundamental concept and play a very important role in modern technology, including Artificial Intelligence. A perfect simple example of an Algorithm is the “Hello World” algorithm shown in the figure below.

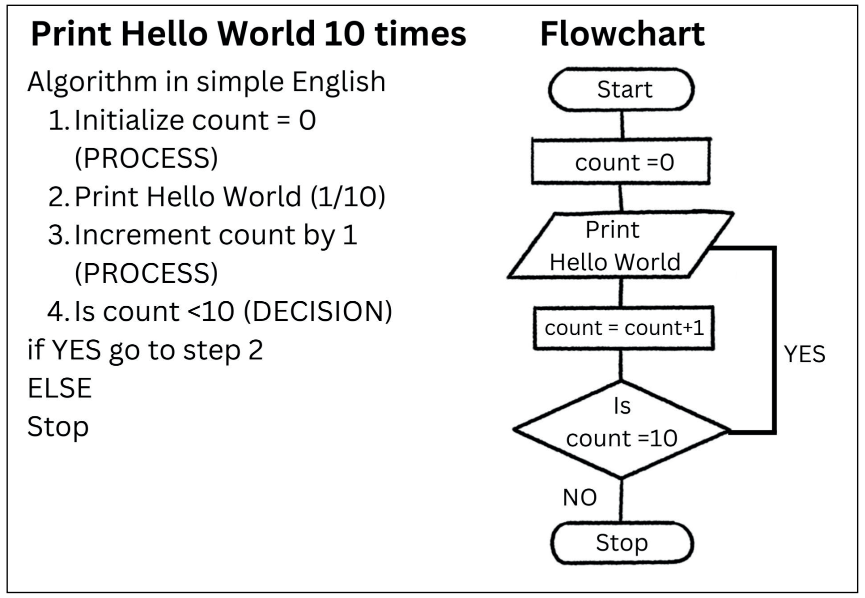

Figure 5 : “Hello World” algorithm [22]

When it comes to algorithms, using the term AI is considered very broad. To understand the depth and logic behind this technology, it is firstly crucial to understand two relevant terms : Machine learning and Deep learning.

Machine Learning:

As a subset of Artificial Intelligence, Machine learning[23] teaches computers to recognize patterns and draw conclusions from data without being specifically programmed for each task. In Machine learning, there is a training set where a computer is trained on a dataset of input-output pairs. The way the program works is by using statistical algorithms and models to be able to identify

21 Alexander S. Gillis, “What Is an Algorithm? - Definition from Whatis.Com,” WhatIs.com, May 19, 2022, https://www.techtarget.com/whatis/definition/algorithm.

22 “Flowchart for “Hello, World!” Program.” AlphaBetaCoder | A Portal for Programming and Source Codes. https://www.alphabetacoder.com/2020/04/flowchart-for-hello-world-program.html.

23 Peter Wittek, Quantum Machine Learning: What Quantum Computing Means to Data Mining (Amsterdam: Academic press, 2016), p.11-24.

patterns and relationships in the data and use this knowledge to make predictions or decisions about new data that it has not seen before.

It is important to note that just like Artificial Intelligence, there are different types of machine learning, the three main ones are (shown in figure 6).

Many different applications, including fraud detection, recommendation systems, speech recognition, image recognition, and natural language processing, use machine learning. The way we process and analyze data has undergone a revolution, and it still encourages innovation in many industries.

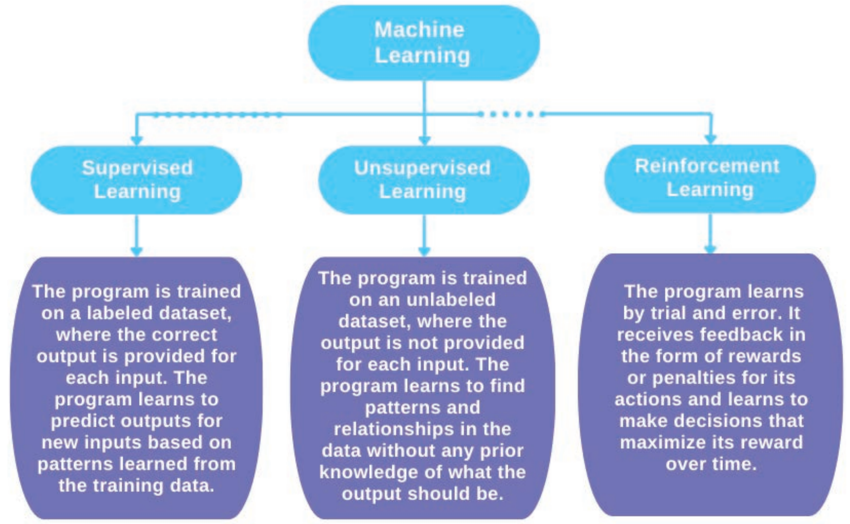

Figure 6 : The Different Types of Machine Learning (Source: Author)

Deep Learning:

Deep learning[24] is a type of Artificial Intelligence that involves training computer programs to recognize patterns in data. It’s like teaching a computer to recognize a face in a photo, or to identify the difference between a mouse and a cat.

Artificial neural networks[25], which are based on the structure of the human brain, are used to implement deep learning. These neural networks are made up of layers of linked nodes that analyze data and learn from it over time. A neuron (shown in figure 7) serves as the fundamental unit within a neural network, performing simple computations

24 Shailendra Shukla, Amit Kumar Singh, and Gautam Srivastava, Internet of Multimedia Things (Iomt): Techniques and Applications (Amsterdam: Academic Press, 2022), p.133-150.

25 Bayya Yegnanarayana, Bayya. Artificial Neural Networks. Twelfth Printing, 2009. p.15-39 https://books.google.fr/books?id=RTtvUVU_xL4C&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false.

by taking inputs, applying weights, and passing the result through an activation function. On the other hand, a neural network (shown in figure 8) consists of interconnected layers of neurons, allowing for complex computations and information processing.

Neurons capture patterns and relationships in the data, while the neural network as a whole serves as a computational framework capable of learning and making predictions. When it comes to deep networks, they are neural networks with multiple hidden layers, enabling them to learn complex representations and hierarchies of features. Deep networks leverage the collective power of neurons in these layers to perform highly sophisticated tasks, such as image recognition, natural language processing, and complex decision-making, making them capable of handling more complex and abstract patterns and data representations. Deep networks refer to neural networks with multiple hidden layers, which enable them to learn and represent more complex patterns and hierarchies of features.

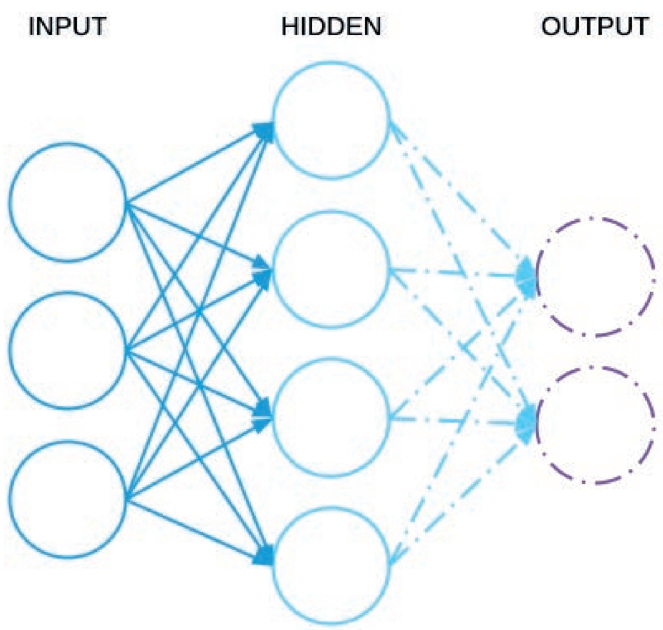

Figure 7 : Image Showing a Simple Neuron (Source : Author)

For example, a neural network is presented with a large quantity of data throughout the training process, and it modifies the weights and connections between its nodes to identify patterns in that data. The neural network will learn to recognize the traits that separate a "6" from an "8," such as the form of the loops or the placement of the lines, for instance, if it is being taught to recognize handwritten numbers.

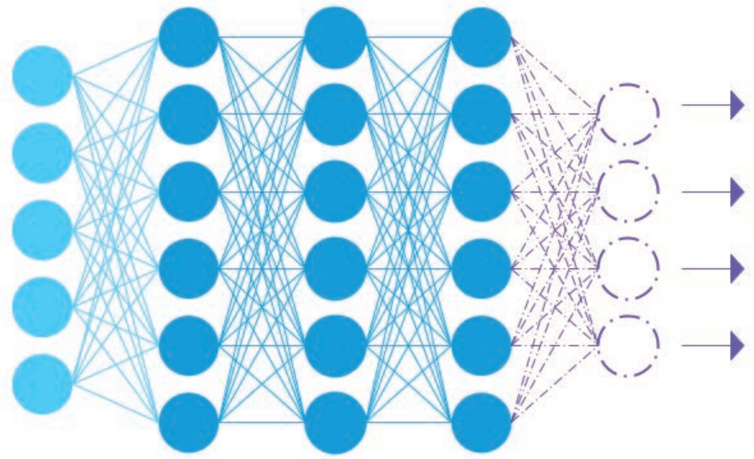

Figure 8 : Image Showing A Neural Network (Source: Author)

Once the neural network[26] has been trained on a large enough dataset, it can be used to make predictions on new data that it hasn't seen before. This is known as "inference," and it is how deep learning is employed in practical applications like image recognition, speech recognition, and natural language processing.

In summary, deep learning is a type of artificial intelligence that uses neural networks to learn from data and make predictions (shown in figure 8). It's a powerful tool for recognizing patterns and making sense of complex information, and it has many practical applications in fields like medicine, finance, and transportation.

Several text-to-image AI systems are available, and in this case study, the focus will be on examining DALL-E 2. The objective is to provide a detailed explanation of how architects can utilize this technology. By exploring the capabilities of DALL-E 2, architects can gain a deeper understanding of how it can enhance their design processes.

26 Bayya Yegnanarayana, Bayya. Artificial Neural Networks. Twelfth Printing, 2009. p.15-39 https://books.google.fr/books?id=RTtvUVU_xL4C&print-sec=frontcover&source=gbs_ge_summary_r&cad=0#v=onep-age&q&f=false.

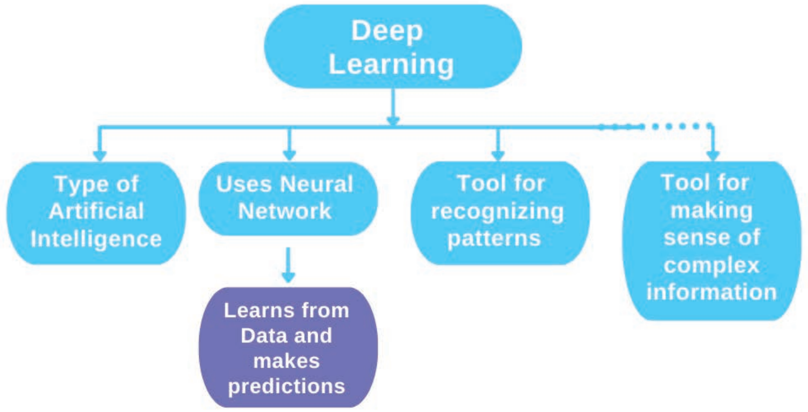

Figure 9: Diagram Summarizing The Roles of Deep Learning (Source: Author)

The case study aims to demonstrate the various ways in which text-to-image AI can benefit architects, including improved visualizations, faster prototyping, and clearer communication of design concepts. By comprehending the potential of DALL-E 2, architects can harness the power of AI effectively and expand their creative possibilities in architectural work.

Case Study : DALL E 2

DALL-E 2[27], developed by OpenAI[28], is a machine learning model that generates images based on user-provided prompts in the form of descriptive sentences (compare examples of existent buildings and generated images seen in figures 10 & 11). It has been trained on a vast dataset consisting of over 650 million images and captions. It's important to note that DALL-E 2 hasn't been explicitly taught what specific things look like, so its outputs are based on its own learned conclusions. As a result, the generated images often have unexpected characteristics.

However, DALL-E 2 offers more than just prompt-to-image generation. It has the ability to expand the canvas beyond the original image, allowing for the creation of larger compositions. Additionally, it can take an existing image as input and generate different variations of that image. Furthermore, DALL-E 2 can modify images by adding or removing elements, taking into account factors like shadows, lighting,

27 Ramesh, Aditya, Prafulla Dhariwal, Alex Nichol, Casey Chu, and Mark Chen. "Hierarchical Text-Conditional Image Generation with CLIP Latents." p. 1–27. https://cdn.openai.com/papers/dall-e-2.pdf.
28 OpenAI. "About OpenAI." OpenAI, Accessed December 11, 2022. https://openai.com/about/.

and blending with the background.

Figure 10: Photo of the inside of the existing Gare Austerlitz[29]

Figure 11: Photo generated by DALL E 2 with the prompt "Gare Austerlitz à la manière de Zaha Hadid" (Souce : Author)

DALL-E 2 has the ability to match images with their corresponding text descriptions. It achieves this using a technique called "diffusion" (shown in figure 12). This technique starts with a random pattern of dots and gradually transforms it into an image by gradually incorporating specific details from the described image.

29 "La gare d'Austerlitz, une halle historique de la Rive gauche." Paris ZigZag | Insolite & Secret. https://www.pariszigzag.fr/insolite/histoire-insolite-paris/histoire-gare-austerlitz-paris.

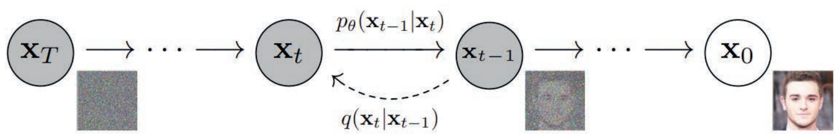

Figure 12: Schematic of the Diffusion Model[30]

To make the most of this tool, which is still in the testing phase, architects can explore how images are created.

The AI generates images that don't actually exist by using a text decoder and an image decoder. However, the important thing to focus on is how the generated image relates to the text prompt. By understanding this connection, architects can communicate better with the text-to-image AI and fully utilize its capabilities. This knowledge allows architects to bring their architectural ideas to life with more accuracy and effectiveness.

The question remains : How does DALL-E 2 understand the visual manifestation of a verbal concept?

In fact, DALL E 2 is trained by another AI called CLIP[31] (Contrastive Language-Image Pre-training). To determine how much a particular text prompt corresponds to an image, CLIP is trained on hundreds of millions of photos and the captions that go with them. In other words, CLIP just learns how closely connected any given caption is to a particular image rather than attempting to predict a caption given an image. CLIP can understand the relationship between textual and visual representations of the same abstract concept thanks to its contrastive rather than predictive function. In simpler terms, CLIP training determines how relatable a text snippet is to a visual concept. As mentioned CLIP has been demonstrated to learn rigorous image representations that capture both semantics and style. OpenAi proposes a two-stage model to leverage these representations for image generation: a prior to map from the text encodings of image captions to the image encodings of their corresponding images (shown in figure 13).

The prior generates a CLIP image embedding given a text caption, and a decoder that generates an image

30 Ho, Jonathan, Ajay Jain, and Pieter Abbeel. "Denoising Diffusion Probabilistic Models." 2 (December 16, 2020): p.1–25. https://arxiv.org/pdf/2006.11239.pdf?ref=assemblyai.com.
31 Ryan O'Connor. "How DALL-E 2 Actually Works." News, Tutorials, AI Research, April 19, 2022. https://www.assemblyai.com/blog/how-dall-e-2-actually-works/.

conditioned on the image embedding (shown in figure 13). DALL-E 2 utilizes a different model, renamed the prior by the authors, to map from the text encodings of image captions to the image encodings of their corresponding images.

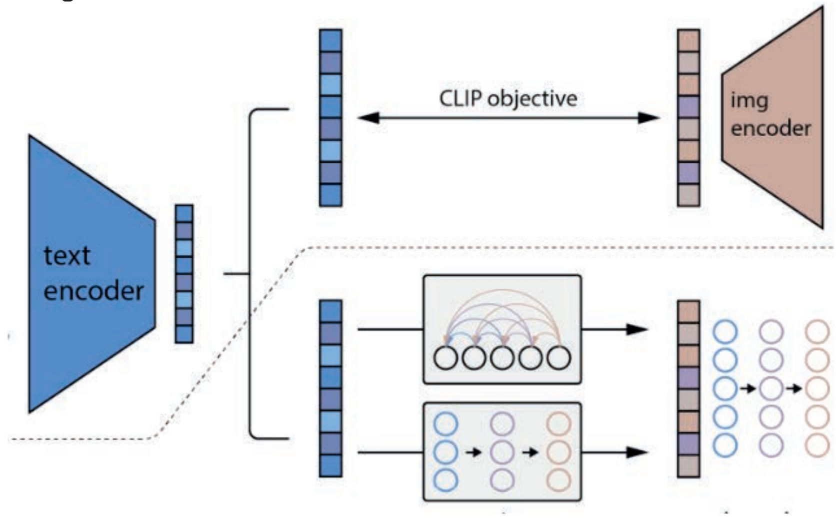

Figure 13: Overview of the CLIP and Prior Image Generation Process[32]

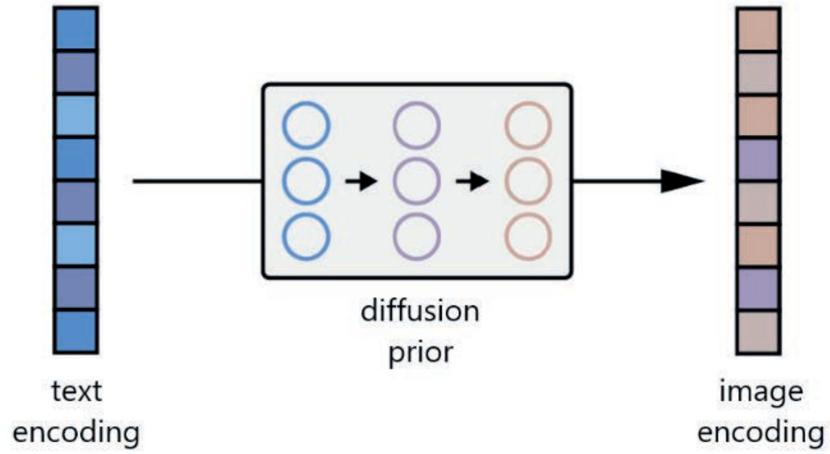

Figure 14: Overview of the Diffusion Prior[33]

As seen in the figure 13, below the dotted line, a CLIP text embedding is fed into an diffusion prior to producing an image embedding (shown in figure 13), which is then used to condition a diffusion decoder, which produces a final image. In simpler terms, when a prior is added to the image generation process, it leads to improved and closer results. The inclusion of a prior provides additional information or guidance, enhancing the quality and accuracy of the

32 Ryan O'Connor. "How DALL-E 2 Actually Works." News, Tutorials, AI Research, April 19, 2022. https://www.assemblyai.com/blog/how-dall-e-2-actually-works/.
33 *Ibid*

generated images. By incorporating a prior, valuable context or constraints are introduced, helping the AI system better understand and interpret the text prompt. This results in images that closely align with the intended outcome. By including a prior, the AI model can generate images that capture the specific characteristics or features requested in the text, bringing the generated images closer to the desired output. Therefore, the addition of a prior enables the achievement of superior results in the image generation process.

As well, text embedding and image embedding (shown in figures 15 and 16) are techniques used to represent textual and visual data in a numerical format for easier computer understanding. Text embedding converts words or sentences into vectors, capturing their meaning and relationships. Similarly, image embedding converts images into vectors, capturing visual features. These techniques enable efficient comparison, search, and analysis of text and images by machines. They are crucial for tasks like text-based search, recommendation systems, and image similarity analysis.

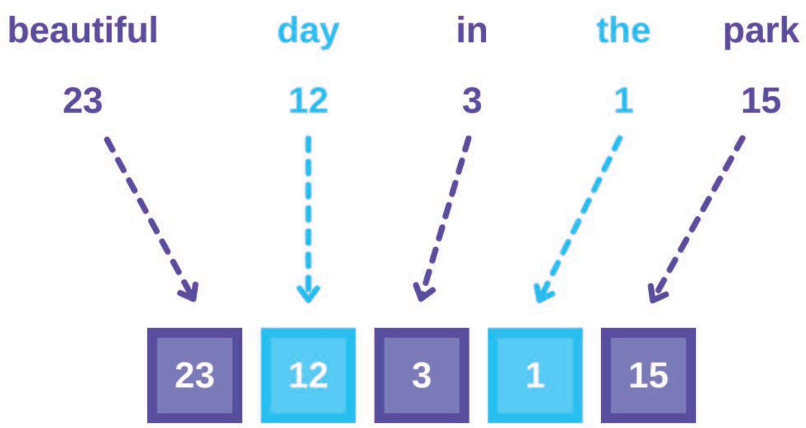

Figure 15: Images Showing The Text Embedding [34]

34 Ryan O'Connor. "How DALL-E 2 Actually Works." News, Tutorials, AI Research, April 19, 2022. https://www.assemblyai.com/blog/how-dall-e-2-actually-works/.

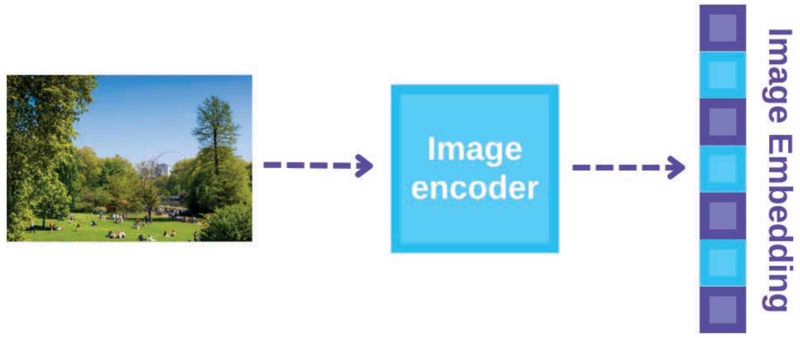

Figure 16: Images Showing The Image Embedding [35]

As well, text embedding and image embedding (shown in figure 14) are techniques used to represent textual and visual data in a numerical format for easier computer understanding. Text embedding converts words or sentences into vectors, capturing their meaning and relationships. Similarly, image embedding converts images into vectors, capturing visual features. These techniques enable efficient comparison, search, and analysis of text and images by machines. They are crucial for tasks like text-based search, recommendation systems, and image similarity analysis.

After completing the CLIP training, DALL-E 2 receives a spatial representation that indicates how well an image corresponds to its text. The next step is to reverse this initial spatial representation of the image. As mentioned before, DALL-E 2 creates new images that don't actually exist. For the next part, another former AI version developed by OpenAI called GLIDE[36], is introduced in order to invert the initial image encoding generated by CLIP.

The goal is to create a new image while maintaining the semantics of the original coded image. Therefore, with GLIDE, a lot of features are taken into account. The modified-GLIDE generation model uses reverse diffusion to map from the representation space into the image space, creating one of numerous images that might be produced to convey the semantic information contained in the input caption.

DALL E 3:

As of September 2023, DALL E 3 is announced as DALL E 2's successor. It promises enhanced abilities in image gen-

35 Ryan O'Connor. "How DALL-E 2 Actually Works." News, Tutorials, AI Research, April 19, 2022. https://www.assemblyai.com/blog/how-dall-e-2-actually-works/.
36 Alex Nichol et al., GLIDE: Towards Photorealistic Image Generation and Editing with Text-Guided Diffusion Models, March 8, 2022, p.1–20, https://doi.org/https://arxiv.org/pdf/2112.10741.pdf?ref=assemblyai.com.

eration as well as “significantly more nuance and detail”. Specifically, the model appears to emphasize the comprehension of prompt semantics. In other words, this model focuses on understanding the meaning of prompts. Managing text-to-image models is a complex undertaking, because they often struggle to show exactly what’s described in the text. This led to the idea of prompt engineering, which is about figuring out how to write prompts that help these models create the right images.
As well, DALL-E 3 is scheduled to become accessible to subscribers of ChatGPT Plus and Enterprise customers starting in October 2023.

ChatGPT is an AI language model developed by OpenAI. It’s designed for generating human-like text responses in natural conversations. Users interact with it via text and can use it for various tasks such as answering questions and creating conversational AI applications. It utilizes the GPT-3.5 architecture to provide contextually relevant responses.

A prominent aspect of DALL-E 3 is its seamless integration with ChatGPT. OpenAI explicitly states that DALL-E 3 is constructed upon ChatGPT, rather than being integrated into it, hinting at a profound connection between the two.

In the context of this research, the continuous evolution of technology presents an opportunity for deeper contemplation. Beyond the availability of a conversational chatbot, there exists a novel integrated image generation capability. This recent innovation by OpenAI may serve as a foundational platform for extended investigations into the reconfiguration of architecture through the utilization of text-to-image artificial intelligence, and potentially, the augmentation of conversational AI.

Conclusion of Chapter 1

This chapter acts as the first step toward comprehending the state of the art of Architectural Artificial Intelligence, tracing its evolution from its conception to its integration into the field of architecture. From this first part, we understand the importance of Generative AI and how architects can use it to generate multiple options and create more optimised solutions. This allows the design professionals to explore a far wider range of design options in a lot less time than traditional design techniques.

Additionally, we have a better understanding of algorithms and the way they function. This makes integrating these algorithms in early stages of the design (the pre-design) possible in order to prevent issues in further phases. In other words, architects can leverage AI’s capabilities to verify the feasibility of their designs even before they are physically realised, thanks to advanced simulations and predictive modelling.

In the next chapter of the article, the experimental phase of this research will involve conducting various tests on different text-to-image AI systems. These tests aim to identify flaws in the generated output and gain a deeper understanding of the process of writing effective prompts. Through this experimentation, valuable insights will be gained into the limitations and potential improvements of text-to-image AI.

2 | Artificial Intelligence & Architecture : An Experimental Perspective

2.1 Evaluating Flaws in the Output

The field of Artificial Intelligence is experiencing a continuous flow of new systems on a daily basis. These emerging AI systems are accompanied by evolving algorithms, allowing for improved performance and accuracy. Simultaneously, users are gaining a better understanding of how to effectively communicate with these machines, enabling more fruitful interactions and productive outcomes. The neural network, the backbone of these AI systems, is also expanding, adapting, and becoming increasingly sophisticated.

Architects are creatives that constantly showcase ideas through graphical representation whether it be plans, elevations, sections or even 3D models. The emergence of generative AI opened up a number of possibilities for architects to improve their workflow and use this tool in the design at different phases of the project. Every architect has a different approach to design, this tool allows through a prompt, the generation of data-driven solutions for informed decision-making in architecture.

This unprecedented growth and development in the field of Artificial Intelligence make research an ongoing process of evolution. The main approach to this research is experimental, wherein systematic tests and trials are conducted to gather valuable findings and data. These experiments are carefully designed, with specific conditions set by the researcher, to ensure the accuracy and reliability of the results obtained. This rigorous approach enhances the credibility of the research outcomes, enabling a deeper understanding of the capabilities, limitations, and potential advancements in the ever-evolving landscape of Artificial Intelligence.

It is important to keep in mind that there are two main objectives of the experiments :

1. Evaluating the flaws in the output (the results)
2. Learning how to write prompt/ how to communicate with Artificial Intelligence using natural language

The research comprises two distinct sets of experiments, each offering unique insights into the field of text-to-image AI. The first experiment spanned a period of 12 months (October 2022- October 2023) and involved conducting a series of tests using the same prompt across various text-to-image AI systems. The objective was to analyze and compare the outputs generated by these systems, thereby discerning the evolution and improvement of the underlying algorithms employed by each text-to-image AI over time.

By examining the progression of the algorithm's performance, valuable observations were made regarding the advancements and refinements achieved by the text-to-image AI systems. The second experiment looked into the world of different architectural scales, focusing on how the accuracy of the generated results is affected when the scale of the space is modified. This investigation aimed to understand the influence of scale on the text-to-image AI systems and identify the most accurate outcomes across various architectural dimensions. By identifying the best-performing results, the intention was to look deeper into the prompt writing process, studying and understanding the factors that contribute to achieving desirable and replicable results. This exploration of the prompt writing process serves as a foundation for enhancing the reliability and effectiveness of the text-to-image AI systems in generating accurate and visually coherent architectural representations.

Through these comprehensive sets of experiments, the research seeks to provide valuable insights into the evolution of text-to-image AI algorithms over time and the impact of architectural scales on the generated outcomes. Furthermore, the study aims to contribute to the development of improved methodologies in prompt writing, enabling architects to more effectively utilize text-to-image AI systems in their design processes.

2.1.1 How to generate images using prompt:

In the case study of DALL-E 2, it becomes evident that a thorough understanding of how the tool operates is crucial before embarking on any experimentation. It is essential to comprehend the underlying mechanisms and algorithms employed by DALL-E 2 to make the most effective use of this text-to-image AI system. This understanding forms the foundation for utilizing the tool in a manner that aligns with the desired outcomes and objectives.

To further illustrate the practical applications of text-to-image AI, let’s consider another example: Midjourney. Launched on July 12, 2022, Midjourney attracted a lot of interest due to its remarkable ability to generate realistic and highly accurate results. Particularly notable was its proficiency in creating renders and 3D images of spaces that embodied the specific architectural style of renowned architects. This capability is exemplified in figure 14, where Midjourney successfully produces visuals that capture the essence and unique characteristics associated with the chosen architect’s style as well as the architecture style chosen (Bauhaus).

By examining the successes and strengths of tools like Midjourney, we gain valuable insights into the immense potential of text-to-image AI systems. These tools can assist architects and designers in producing visually compelling and contextually relevant architectural representations, enabling them to effectively communicate their design concepts and ideas. Through continued exploration and understanding of such advancements in the field, architects can harness the power of text-to-image AI to unlock new possibilities and push the boundaries of architectural visualization

Figure 17: Images Generated on Midjourney - Prompt used : “Villa Savoye, Bauhaus, Mies Van Der Rohe” - 20/10/2023 (Source: Author)

After initial experimentation with the tool, it was determined that as an AI art generator, the algorithm and its results are effective up to a certain extent. However, it was recognized that a visually pleasing image generated by AI can serve more as inspiration rather than a direct foundation for a project. To explore this further, the subsequent phase of testing focused on determining whether AI could generate multiple options for a plan, section, elevation, or even a complete 3D model.

This phase aimed to assess the tool's ability to produce diverse alternatives and expand its utility in the architectural design process.

2.1.2 The First Experiment

The first phase of experiments lasted for 12 months (October 2022 - October 2023), providing ample time to thoroughly explore and understand the subject. The main goal of these experiments was to examine and assess the results produced by different AI systems when given the same prompt. By using multiple AI systems, researchers aimed to compare and contrast their outcomes, which helped them understand the unique characteristics and abilities of each system. A key aspect of the experiments was examining the content stored in the databases of each AI model. Researchers delved into these databases to uncover a wide range of information used to train the AI models. This investigation aimed to evaluate the quality and relevance of the data, giving researchers a better understanding of the knowledge base and its influence on the generated outputs.

Every architect has their own unique way of conceptualizing projects. Some rely on traditional methods like plans, sections, and elevations, while others explore different mediums and tools. When the text-to-image AI tool was discovered, it raised an important question: How reliable and precise is this tool? As an architect, the curiosity arises whether this tool can be effectively utilized to enhance and expedite the design process in the most efficient manner. Architects are problem solvers looking for efficiency in the design process. They are also intuitive when it comes to designing spaces and making decisions. The architect's mindset revolves around working smarter rather than harder. Architecture represents a complex discipline with all of knowledge, history and references that date back. The more experienced an architect is, the better his database, the better the results because the conclusions are made on the basis of the accumulation of more data.

AI presents an opportunity for new graduate architects to achieve impressive project outcomes by utilizing AI as a vast database of knowledge. Architectural history spans thousands of years, and no single architect can fully study and implement all the accumulated knowledge. However, the AI text-to-image model has undergone extensive deep learning using a massive online database. Furthermore, it continuously updates its algorithm to generate increasingly accurate and reliable results. To effectively utilize this tool, architects must learn how to communicate with it, understanding which words to use, the optimal length of the text prompt, and which keywords yield the best outcomes. Additionally, it is crucial to consider the extent of data available in the AI's database regarding specific architects and their works.

By tapping into the capabilities of AI, architects can leverage its vast knowledge and adaptability to enhance their own design processes. AI serves as a powerful tool, bridging the gap between an architect's individual expertise and the immense wealth of architectural knowledge accumulated over centuries.The first experiment can be summarized as follows (as seen in figure 18):

1. Write one prompt describing a space you wish to create
2. Use the same prompt on different text-to-image AI
3. Compare results by the different text-to-image AI over the period 9 months
4. Make a conclusion on the evolution of the results and the algorithm behind it

There are multiple text-to-image AI that exist, however, the experiment was conducted on 3 text-to-image AI :

1. midjourney[37] (developed by an independent lab, released July 2022)
2. DALL E 2 (developed by OpenAI, released April 2022)
3. DreamStudio[38] (developed by Stable Diffusion)

37 Oppenlaender, Jonas. "The Creativity of Text-to-Image Generation." October 30, 2022. https://arxiv.org/pdf/2206.02904.pdf.
38 "DreamStudio: Stable Diffusion's AI Art Web App Tool Explained." Built In. . https://builtin.com/artificial-intelligence/dreamstudio.

They have similar algorithm systems, however the experiment displays different outputs when using the same prompt. The prompt used is :

“a floor plan of a residential apartment, 100 m², 2 bedrooms, one kitchen, one living room, 2 bathrooms and a balcony, add doors and windows and proportions, blueprint, architecture, design housing, 2D, sketch, like AutoCAD”

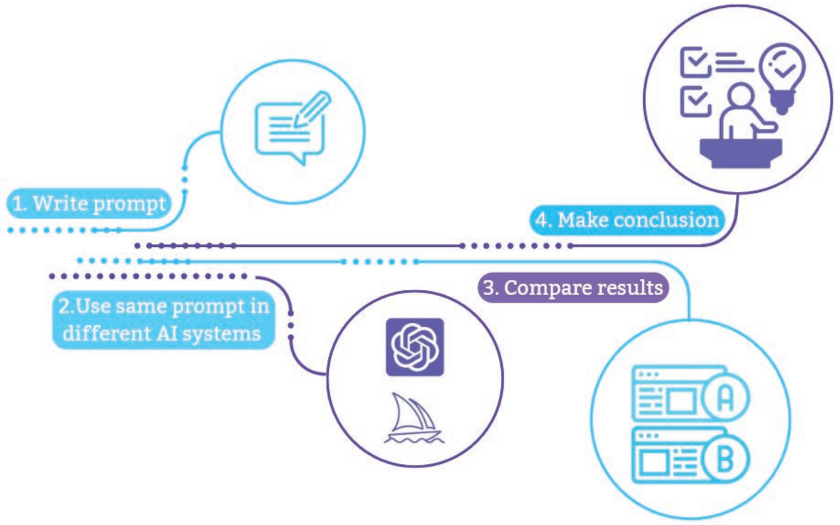

Figure 18: Summary of The First Experiment (Source: Author)

The Results:

As a new user of midjourney, or text-to-image AI in general, the intent was to have a personal link to the tool and give back feedback on:

the experience,
the input used,
the output,
the interface,
and then finally make a conclusion.

The initial testing began in October 2022 on three different text-to-image AI systems (mentioned above).

Mainly, the way the experiment works is : the user (the author) inputs the prompt (the text description) and then the text-to-image AI (midjourney or DALL E 2) outputs variations in image form. The user then has three options:
either asks the text-to-image AI to create completely new variations, either he decides to create new variations based on one of the variation of his choice,
either he upscales one of the variations presented (that means he can get a more detailed, less pixelated, version of the variation of his choice)

Now, what this procedure does is, first, it showcases first hand how the user and the machine work together, and second, it tells us how the machine learns from the choices made by the user. It acts as a sort of training and therefore, as a result, in the next tables of results, you can actually see the evolution of this tool from its launch till this day (over a period of approximately 9 months).

Figure 19: Image Showing 2 Results of The First Experiment on Midjourney, 29 October 2022 (Source: Author)

This first Outputs table shows the results of October 2022 (shown in figure 19). The prompt used is the same mentioned earlier:

“a floor plan of a residential apartment, 100 m², 2 bedrooms, one kitchen, one living room, 2 bathrooms and a balcony, add doors and windows and proportions, blueprint, architecture, design housing, 2D, sketch, like AutoCAD”

The prompt specified the required area, the program (such as an apartment or residential space), and provided an example of the desired draft format, such as AutoCAD. The objective was to assess the AI’s capability to generate a plan with proper lineweight, accurately incorporating the requested rooms, achieving desirable proportions, and ensuring efficient circulation, among other factors.

Regarding the results obtained from midjourney, it is evident that it did not fully comprehend the given prompt. Upon reviewing the table, certain outcomes displayed only partial lines and empty spaces, indicating incomplete representations. However, some results did exhibit appropriate lineweight and distinctions within specific areas. Nonetheless, many proposals appeared fragmented and lacking necessary information regarding the purpose of each space. Consequently, it can be concluded that the generated outputs are not conducive to architectural work, as most of the plans lack coherence and fail to convey a clear meaning.

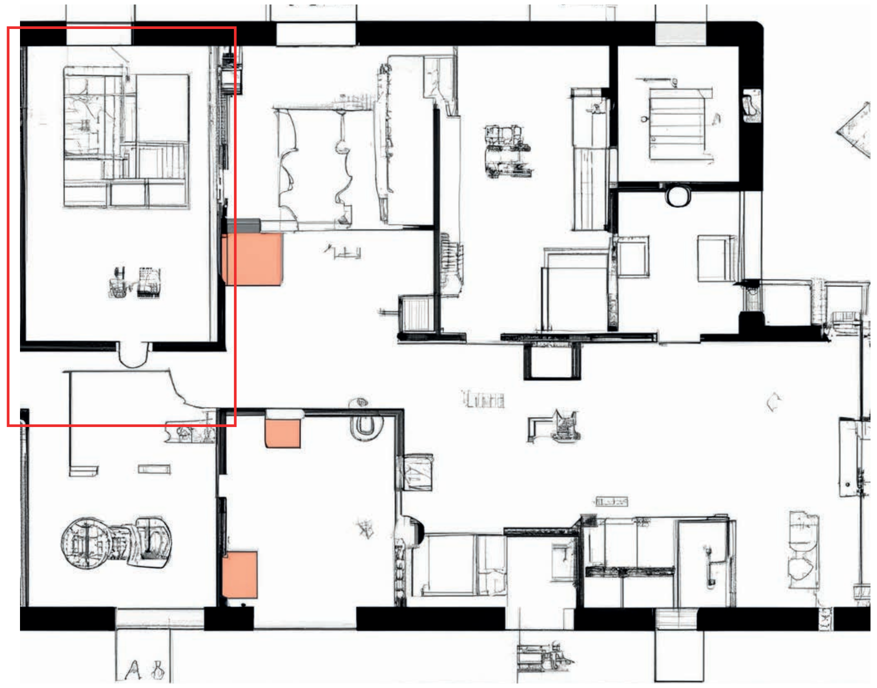

Figure 20: Image Showing one Result of The First Experiment on DALL E 2, 29 October 2022 (Source: Author)

In examining the outcomes generated by DALL E 2 in figure 20, a notable refinement and detail enhancement are observed in the graphical depiction of walls and windows. The varying line weights contribute to an improved visual representation, showcasing an effort to articulate the program of each place, despite the text's ambiguous nature. However, certain anomalies become apparent upon closer inspection.

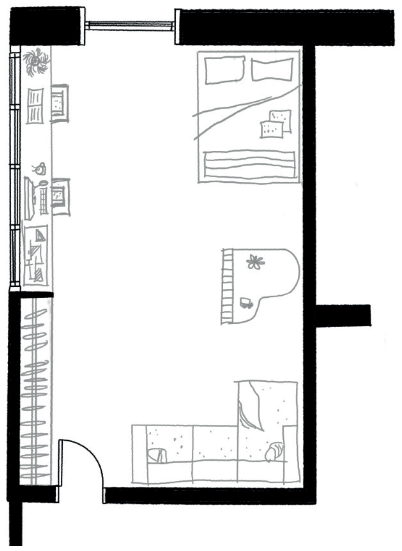

Figure 21: Image Showing a sketch of the area in red of the figure 20, a reinterpertation of how the space could be (Source: Author)

Notably, doors are absent or misrepresented, and some windows are positioned in peculiar locations. Floating elements defy comprehension, and the inclusion of furniture, while present, exhibits inaccurate proportions. Moreover, the absence of doors and misplacement of windows contribute to spatial inaccessibility, with instances of furniture obstructing room entry points. The lineweight inconsistency, ranging from blurry to varying thickness, further adds to the perplexity. Some rooms lack windows entirely, creating enclosed spaces devoid of access. The overall proportions of elements appear disjointed and disorganized, with furniture seemingly arranged haphazardly, lacking a coherent or purposeful arrangement. These observations shed light on the intriguing yet often nonsensical nature of the images produced by DALL E 2 in response to the experiment's prompts. We can also see in the red rectangle a zone of the plan that I tried to re-imagine in figure 21. The purpose is to show how this space could be re-created with the use of the initial generated plan as a basis.

The final AI system examined is DreamStudio (results shown in figure 22), a generative media tool developed by Stable Diffusion that aims to provide freedom of imagination and facilitate visual expression. The initial test involved using the same prompt for all images, as depicted in the first two examples.

Figure 22: Image Showing The Different Results of The First Experiment on DreamStudio, 29 October 2022 (Source: Author)

The second set of images was part of a smaller, separate experiment. In the initial test, the results are noticeably clear and detailed. There are some notable details to observe, such as the somewhat symmetrical spatial arrangement. Additionally, the images feature furniture, and the proportions appear somewhat accurate. By looking at the images, one can determine whether they represent a dining room or a living room.

This tool at that time (October 2022) was the only one to give out this better level of results. As a consequence, another set of experiments for this particular tool was conducted, to test its performance and limits. The next two images are the output of the following prompt:

“let’s think things through step-by-step, a 2D square plan, composed of one bedroom, a small kitchenette, and a bathroom, 4k, like AutoCAD drawing, for architects, good proportions, has doors and windows, written in English, not symmetrical”

The reasoning behind this prompt is to make it simpler and clearer. DreamStudio has implemented another feature that adds more parameters and accuracy to the kind of results a user wants to achieve (shown in figure 18). Mainly, the idea was to recreate the prompt with minimum to a maximum of parameters available to see how different and elaborate the result can get. As it can be seen on the image to the right, there are multiple parameters to choose from such as the width, height, etc. The part that is particularly intriguing is the Cfg Scale : It modifies how precisely the output is to the written prompt. Additionally, for greater accuracy, the user can specify the amount of steps or layers they want the machine to generate to create the image.

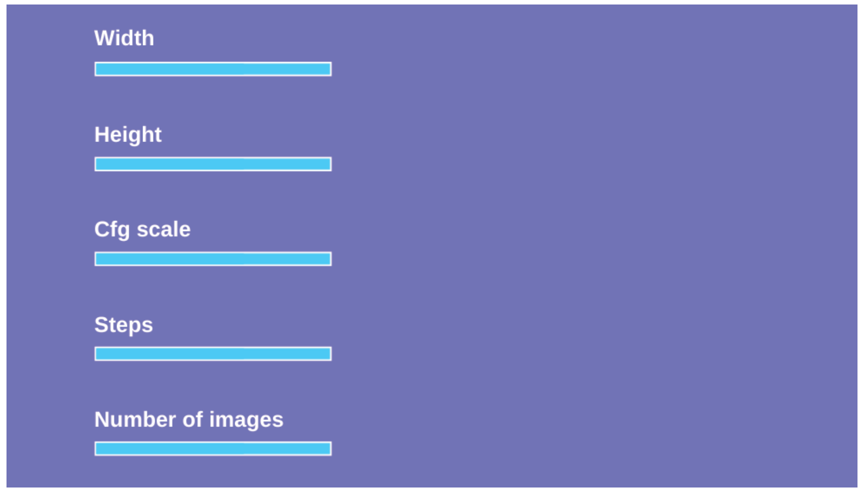

Figure 23: The Different Parameters Settings in DreamStudio

There are three generated images from the prompt mentioned above for the second set of testing. The prompt is the same for each generated image, the only difference is the parameter setting.

The initial testing, as depicted by Test 1 in the graphic above (shown in figure 24), demonstrates the result obtained from the prompt without making any alterations to the default parameter settings. The outcomes of this initial test reveal the accurate depiction of various spaces such as bedrooms, bathrooms, and kitchen as described in the prompt. Furthermore, the generated image also exhibits a clear representation of doors and windows, adding to the visual coherence and comprehensibility of the output.

The second round of testing, indicated by Test 2 in the graphic above (shown in figure 24), showcases the outcome of the prompt when higher values are set for both the Cfg Scale and Steps parameters. This adjustment leads to a more accurate and precise representation of the prompt, as the machine undergoes additional layers of processing, as illustrated in figure 8, which explains the functioning of neural networks[39] and deep learning[40].

Analyzing the results obtained from this test, we observe

39 Bayya Yegnanarayana, Bayya. Artificial Neural Networks. Twelfth Printing, 2009. 15-39 https://books.google.fr/books?id=RTtvUVU_xL4C&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false.

40 Shailendra Shukla, Amit Kumar Singh, and Gautam Srivastava, Internet of Multimedia Things (Iomt): Techniques and Applications (Amsterdam: Academic Press, 2022), 133-150.

that the generated image takes the form of a 2D plan, characterized by a square spatial composition. However, some misinterpretations or inconsistencies persist. For instance, the bedroom is missing from the plan, raising questions about the divisions made within the space and leaving room for potential modifications. Additionally, the doors depicted in the image appear to be rotating in the wrong direction, further highlighting the need for refinement in certain aspects of the output.

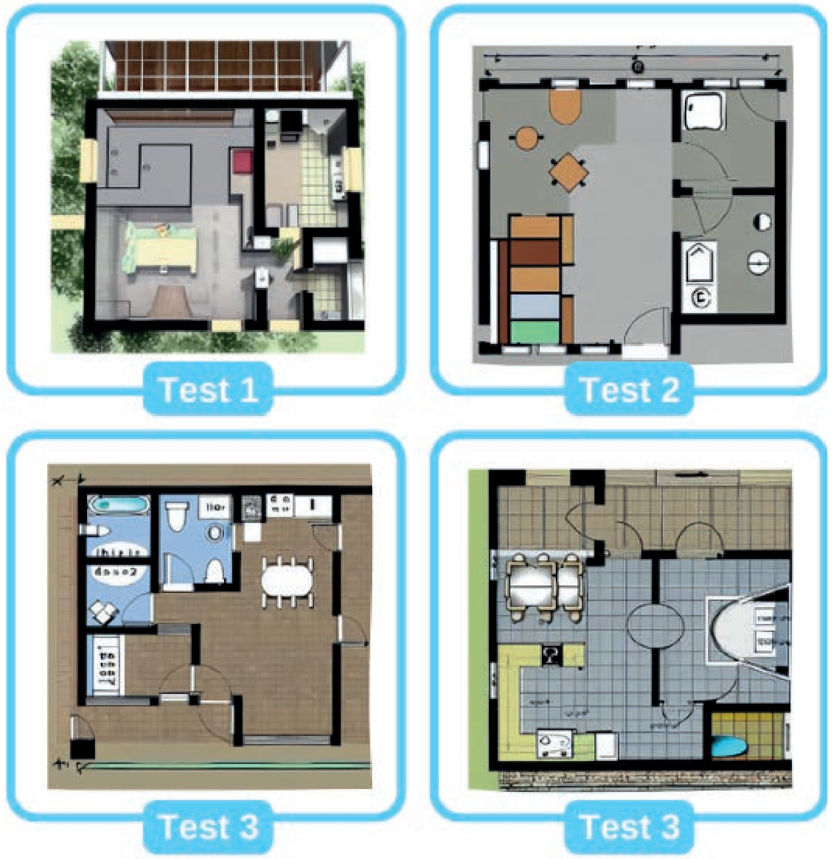

Figure 24: Image Showing The Different Results of The Second Experiment on DreamStudio, (Source: Author)

The third round of testing, depicted by Test 3 in the graphic (shown in figure 24), unveils the most precise and accurate results. The prompt used remains the same, while the parameters Cfg Scale and Steps are set to their maximum values. Across all three variations, notable improvements are observed, including:

1. Better composition: The overall arrangement of the elements within the generated images demonstrates improved spatial organization.

2. Enhanced divisions in the space:The plan's structure and distribution of the various areas show borders that are more clearly defined.

3. Somewhat correct proportions: Notably, the proportions in the bathroom section appear to be more accurate compared to previous tests, indicating a step toward improved fidelity.

4. Presence of doors: The inclusion of doors in the generated images indicates a better understanding of architectural elements and their placement.

5. Square aspect of the plan: Consistency in the square shape of the plan is evident, suggesting a more precise interpretation of the prompt's spatial requirements.

These advancements highlight the effectiveness of utilizing higher parameter values in achieving improved output quality, resulting in more desirable and reliable outcomes.

2.1.3 The Evolution of midjourney Over Time

As previously discussed, the primary objective of the first experiment is to visually showcase two key aspects:

1. The level of development of the machine in accurately capturing the essence of the prompt: Through the generated images, this experiment aims to highlight the machine's progress and proficiency in understanding and translating the given prompts into visually representative outputs. By examining the results across different variations, we can observe the machine's ability to improve its accuracy and alignment with the intended prompt.
2. The rapid pace of the learning capability of the neural network powering the text-to-image AI: This experiment also aims to emphasize the remarkable speed at which the neural network, the underlying technology behind the text-to-image AI, learns and adapts. The neural network's capacity to swiftly analyze vast amounts of data and adjust its algorithms enables the machine to continuously enhance

its output quality and align it more closely with the intended prompt.

By visually demonstrating these two aspects, the first experiment provides valuable insights into the machine's development trajectory and the impressive learning capabilities of the neural network, underpinning the advancement of the text-to-image AI technology.

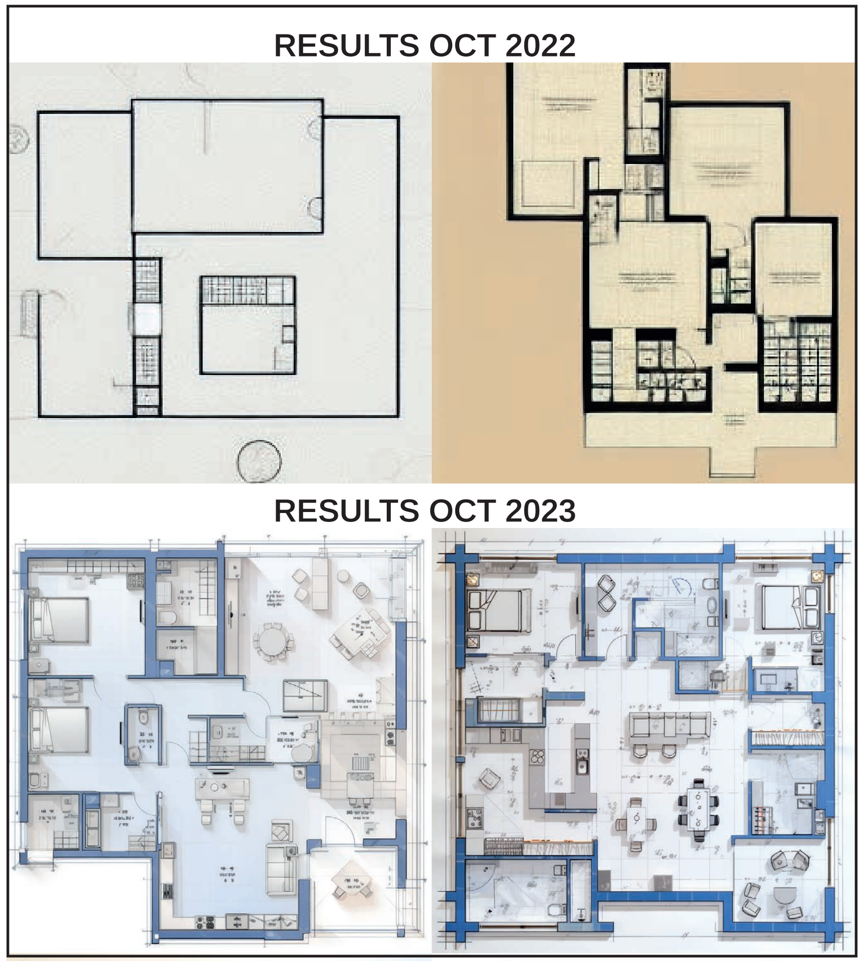

Figure 25: Image Showing The Evolution of The Different Results of midjourney Over The course of 12 Months Using The Same Prompt "a floor plan of a residential apartment, 100 m², 2 bedrooms, one kitchen, one living room, 2 bathrooms and a balcony, add doors and windows and proportions, blueprint, architecture, design housing, 2D, sketch, like AutoCAD" (Source: Author)

The comparative table presented (shown in figure 25) showcases the results obtained from two different time periods: October 2022 (around 3 months after the launch of midjourney) and October 2023 (12 months after its launch). The purpose of this comparison is to highlight the significant progress made by the machine within a span of 12 months.

Upon examination of the results from October 2023, it becomes evident that the machine has achieved a much higher level of understanding and capability. The generated outputs, at first glance, resemble pre-design sketches or actual architectural plans, indicating a substantial improvement in the machine's ability to capture the essence of the prompt and translate it into visually coherent representations. Moreover, there is a noticeable increase in precision when it comes to the textual elements present in the generated documents, along with the inclusion of dimensions, further enhancing the accuracy and completeness of the outputs.

The results obtained in October 2023 offer a wealth of observations and insights. The advancements made by the machine over the 12-month period are remarkable, with notable improvements in various aspects, including the overall quality of the generated plans and the level of detail incorporated within them.

The evolution of midjourney over time can be attributed to a multifaceted interplay of various factors. At its core, the hypothesis revolves around the dynamic synergy of several elements. The quality and diversity of training data contribute significantly, shaping the model's understanding and adaptability. The intricacies of the model architecture play a pivotal role, influencing how information is processed and synthesized. Prompt engineering, another crucial aspect, guides the interaction and response mechanisms, fine-tuning the model's output. Concurrently, the progression is propelled by ongoing research advances, incorporating the latest insights into the system. Additionally, the dynamic interplay between user and machine training adds a nuanced layer, refining the model through iterative learning experiences. In essence, the evolution of midjourney is a complex combination of these elements, each contributing uniquely to its continuous refinement and enhancement over time.

Subset Experiment

As part of a secondary subset of the experiment, a group of practicing architects employed at AREP[41] were invited to provide their input on the plans generated by midjourney. Their objective was to offer comments, make drawings, or suggest adjustments to the plans created by the AI system.

By involving these experienced architects in the evaluation process, researchers aimed to gather valuable insights and perspectives from professionals actively engaged in the field. The architects were given the opportunity to critically analyze the plans generated by midjourney and provide their expert opinions on the strengths, weaknesses, and potential improvements of the AI-generated designs.

This collaborative approach allowed for a more comprehensive assessment of the machine's outputs by incorporating the valuable expertise and creative judgment of architects. By incorporating the feedback and adjustments proposed by the practicing architects, researchers aimed to enhance the usability and practicality of the AI-generated plans, ultimately bridging the gap between AI technology and architectural expertise.

The inclusion of architect intervention in this study serves to gain a fresh perspective on the subject matter. Practicing architects, who are intimately familiar with the demands of real-world projects and work within specific time constraints, bring a practical and rational viewpoint to the evaluation process. These professionals constantly seek ways to enhance their efficiency throughout the design process, encompassing various project phases from initial conceptualization to construction and on-site work.

The architects selected for this intervention are experienced team leaders with a minimum of 5 years of practical experience. Their expertise and insights are invaluable in assessing the capabilities and limitations of text-to-image AI. To provide context, these architects were interviewed and asked to share their thoughts on several key questions.

Firstly, they were asked to express their opinions on text-to-image AI, providing their overall impressions and reflections on this emerging technology. Secondly, the architects were invited to describe the relationship between architects and text-to-image AI, exploring how these two entities interact

41 "Manifesto - AREP." AREP. .Accessed May 22, 2023 https://www.arep.fr/en/agency/manifesto/

and collaborate in the design process. Lastly, they were prompted to envision the practical use of text-to-image AI as a tool, considering its potential applications and integration within different project phases (exact questions of the interview shown below.

1. What do you think about text-to-image AI?
2.How would you describe the relationship between the architect and the text-to-image AI?
3. If text-to-image AI was described as a tool, how would you imagine the use of this "tool" in the design process or the different phases of the project?

By gathering insights from experienced architects, this research aims to gain a deeper understanding of the implications, challenges, and opportunities presented by text-to-image AI. The architects' perspectives shed light on the practicality and feasibility of incorporating this tool into the design process, ultimately informing the development and improvement of AI systems to better serve the needs of architects and enhance their workflow.

The General Perspective:

Before diving into the architects' responses, it is crucial to note that they were provided with a comprehensive understanding of the research objectives, including the background information on the experiments and the usage of text-to-image AI. They were familiarized with the evolution of the results obtained over time, as demonstrated in the paper. Armed with this knowledge, the architects approached the plans generated by the AI with a sense of anticipation and curiosity.

Initially, the architects were astounded by the plans and their immediate visual impact. They were impressed by the apparent functionality and clarity of the graphical representation. The initial impressions were indeed positive, and the architects were captivated by the generated plans.

However, upon closer examination and upon being asked to analyze the plans more thoroughly, the architects' responses took a different turn. As they inspected the plans in greater depth, they began to identify areas that raised concerns and limitations. These observations highlighted the complexity and nuance of architectural design, which cannot be fully captured by a purely automated process. The architects' contrasting reactions illustrate the need for a comprehensive evaluation of the AI-generated plans. While the initial visual appeal may be persuasive, a deeper examination reveals the complexities and challenges involved in translating architectural intent and design principles into tangible plans.By soliciting the architects' insights and exploring their nuanced reactions, this research attempts to gain a comprehensive understanding of the strengths and limitations of text-to-image AI in the context of architectural design. These observations contribute to the ongoing development and refinement of AI tools, helping bridge the gap between automated generation and the detailed decision-making processes of architects.

Figure 26: Graphic Displaying Comments Made By Architects From AREP Group On Plans Generated By midjourney, 23-05-2023, (Source: Author)

During the architect interventions, a range of comments were shared (some are shown in the figure 26), offering valuable insights into the current state of the AI-generated plans. While the following comments provide a glimpse into the architects' perspectives, it's important to note that there were many more comments that contributed to a comprehensive understanding of the plans' quality and limitations.

The primary objective of these interventions was to shed light on the progress and development of midjourney. Despite its impressive and rapid evolution, it became evident that the tool still has room for improvement. The architects recognized that the training and refinement of AI tools are ongoing processes that require continuous input and guidance from architects themselves.

One architect kept insisting on a crucial point throughout the discussions: AI should always be regarded as a tool. This viewpoint emphasized that while AI can assist and enhance the design process, it should never replace the expertise and creativity of architects. The role of architects in shaping and refining AI tools remains essential, ensuring that the technology remains aligned with their vision and goals.

These comments highlight the dynamic nature of the interaction between architects and AI tools. As the field of architecture continues to evolve, so too will the relationship between architects and AI. The ongoing collaboration and feedback from architects will play a pivotal role in shaping the future development and utilization of AI as a valuable tool in the architectural design process.

During the interventions, an architect attempted to make one of the plans more functional by making adjustments. However, halfway through the process, the architect stopped and expressed that it would be easier to start the sketch from scratch rather than trying to correct the plan generated by AI. Not all plans required a complete redesign, though. Surprisingly, there was one plan that an architect found to be functional. The architects also raised questions about how these plans would be implemented.

Up to this point, all the plans created by midjourney represented an abstract space without specific spatial limits. This freedom allowed for flexibility in determining the plan's footprint and layout.

2.1.4 Text-to-Image AI as a Tool in the Design Process: Insights from Practitioners

Text-to-image AI serves as a valuable source of inspiration and can be utilized at the initial stages of the design process. It offers a range of possibilities, from generating rough sketches to creating more detailed plans or sections. However, it is crucial to view these generated images as a starting point or a foundation for design, rather than a final solution. By treating them as inspirational tools, architects can explore new ideas and unlock untapped creative potential.

The potential of text-to-image AI extends beyond the pre-design phase. Once a design direction has been established, architects can once again leverage the capabilities of text-to-image AI to generate ideas and refine individual units or smaller spaces within the overall design. For instance, architects can use the AI model to explore various details and elements within specific rooms. This repetitive process allows for a continuous dialogue between the architect's vision and the AI-generated suggestions, fostering a collaborative approach to design refinement.

The repetitive nature of using text-to-image AI in the design process allows architects to dive deeper into the exploration of each space and uncover innovative possibilities. By embracing this approach, architects can harness the power of AI as a creative tool to enhance their design process, spark new ideas, and push the boundaries of traditional design thinking.

Conclusion of The First Experiment:

This initial set of experiments sheds light on two key aspects of utilizing text-to-image AI:

1. The Rapid Training Potential: These experiments highlight the remarkable training capability of text-to-image AI within a relatively short time frame. The AI system exhibited significant progress and improvement, demonstrating its ability to learn and adapt quickly. This rapid training potential is a testament to the power of machine learning algorithms and the vast amount of data the AI model has been exposed to. It showcases the potential for continuous development and refinement of the AI's output as it becomes more exposed to diverse architectural prompts.

2. Architect Decision-Making: The experiments also underscore the critical role of architect decision-making when utilizing text-to-image AI as a tool. While the AI system generates outputs based on the provided prompts, architects play a vital role in guiding and interpreting the generated results. Architects must carefully assess and make informed decisions about the AI-generated designs, considering factors such as functionality, aesthetics, and practicality. The tool serves as a collaborator, providing suggestions and inspiration, but ultimately, architects exercise their professional judgment and expertise in refining and shaping the final design.

By recognizing the power of text-to-image AI in its rapid training potential and the importance of architect decision-making, architects can leverage this tool effectively in their design process.

The combination of AI's ability to learn and adapt quickly and the architect's discerning eye and expertise contributes to a collaborative and dynamic approach to architectural design.

2.1.5 The Second Experiment

The second experiment focuses on studying the results created by users of midjourney in more detail. Specifically, researchers collected data from public images that were generated during the free trial of midjourney. To find these images, it was important to use the right keywords during the search.

By using the appropriate keywords, I was able to locate and gather a large dataset of images created using midjourney. This dataset became the basis for a thorough examination of the designs and solutions produced by architects during their trial period. The goal was to understand the strengths, weaknesses, and areas for improvement of midjourney as an AI tool.

By analyzing the results and studying the collected data, researchers gained valuable insights into how midjourney performed and how users experienced it. This understanding helped to refine and enhance the tool, making it more effective and user-friendly. The second experiment aimed to use the insights from user-generated results to improve midjourney as a useful tool for architects in their design process.

Initially, my objective was to assess any updates or advancements in midjourney since my previous testing (in March 2023). To achieve this, I conducted a search using specific keywords to obtain relevant results. The keywords I used were centered around architecture plans, such as “architecture plan,” “architecture overview plans,” “architectural floor plan,” and “architecture floor plan.”

By employing these specific keywords, I aimed to retrieve a selection of generated results that aligned with the architectural context I was exploring. The intention was to examine how midjourney had evolved in terms of its ability to generate accurate and detailed architectural floor plans.

Analyzing the outcomes associated with the chosen keywords provided insights into the improvements, if any, in midjourney’s performance and its effectiveness in generating architectural plans. This examination aimed to determine the extent to which midjourney could assist architects in creating comprehensive and visually appealing floor plans for their projects.

In the second experiment, my primary objective was to explore the variations in architecture based on different sizes. I was particularly interested in studying buildings and structures across a range of scales, from large-scale designs to small-scale details. To accomplish this, I conducted a series of investigations and analyses. The initial findings from this experiment unveiled a set of architectural plans that exhibited similarities to the approach I had employed in my previous experiment. These plans provided valuable insights into the potential implications of scaling in architectural design, paving the way for further exploration and experimentation in my research.

The provided figure below (figure 27) offers an overview of the results obtained by other users who utilized the mentioned keywords. It presents a visual representation of the outcomes, providing a glimpse into the recent developments as the images were sourced from the month of May 2023. These images offer an up-to-date perspective, capturing the latest trends and information related to the specified keywords. By examining this visual display, users can gain valuable insights into the current landscape and state of affairs pertaining to the subject matter.

@pourebadi	*architectural villa floor plan sketch with detailed plans and section Just like the AutoCAD program --v 5*
@bu444	*architectural plan of 3x6 meters living room with a kitchen, sofa, dining table, conceptual drawing --v 5*
@pupsicat	*Please draw an architectural floor plan of a summer cottage with an open kitchen, a living room with a fire-place, two bedrooms, a sauna, and a sauna changing room*

Table Showing the Prompts of Other Users of Midjourney

As seen in the prompts table above, the users asked mid-journey with a sentence : An architectural plan + the pro-gram (kitchen, living room, etc.) + conceptual drawing/ detailed / like AutoCAD program

The sentence is characterized by its simplicity and directness, conveying the intended message without unnecessary elaboration. Despite the lack of extensive precision or intricate details, the machine was able to generate results that effectively addressed the prompt. Even with limited specifications, the machine managed to deliver responses that accurately fulfilled the given task or inquiry. This demonstrates the efficiency and effectiveness of the machine’s performance in generating relevant and suitable outputs, despite the absence of intricate specifications.

Figure 27: Image Showing The Different Results of Users of midjourney in May 2023 Using a Prompt with "architectural plan" Included As Keyword (Source: Midjourney)

2.1.6 Learning to Create Text-to-image AI Prompt

This guide explores the process of creating an effective prompt for generating architectural floor plans using Text-to-Image AI.

Definition of a Prompt:
A prompt is a set of instructions given to artificial intelligence (AI) systems to generate specific outputs, tailored to the user's needs. In architectural design, crafting an effective prompt is a skill that involves breaking down the instruction into several key components.

Task:
The Task is the heart of the prompt, and it's mandatory. It outlines the primary action you want the AI to perform. Always begin the Task sentence with an action verb, like "Generate," "Analyze," or "Draw." For instance, a clear Task could be, "Analyze the light pollution in Beirut, near the waterfront in the residential area, and give me a summary of your findings." This helps the AI understand precisely what needs to be done.

Context:
Context is crucial for refining the AI's response. It involves providing necessary background information by answering questions such as the user's background, the definition of success, and the environmental context. For example, if the architectural project is on a family-owned land with a traditional background and a preference for local materials, this information guides the AI in generating more relevant designs.

Examples/Reference:
While not mandatory, Examples/Reference can enhance the AI's output. This involves mentioning works by famous architects or referring to specific architectural styles. For instance, you might instruct the AI to "Use the 5 pillars of architecture developed by Le Corbusier" to influence the design.

Persona / Avatar:
Persona is an optional component where you can imagine a specific person, like a famous architect, and instruct the AI to design as if that person were doing it. This creative touch adds a personal flair to the AI-generated designs. For example, "sketch like Frank Gehry" could help with a better output based on this architect's sketch style.

Format:
Format, also optional, guides the visual presentation of the end result. It helps to have a clear idea of how you want the AI-generated design to look. For instance, you might specify, “Plan, black and white, focusing on clear lineweights,” or “A conceptual sketch, freeform.” This ensures the AI understands the visual requirements of the task.[42]

Balancing these components in a prompt is an art, ensuring that the AI not only understands the task but interprets it in line with the architect’s vision. Mastering prompt engineering empowers architects to fully utilize AI technology, enriching the intersection of architecture and artificial intelligence.

Conclusion of Chapter 2

In conclusion, the rapid advancements in Artificial Intelligence have led to a constant influx of new systems and algorithms, revolutionizing the field. Researchers and users alike are gaining a deeper understanding of how to effectively communicate with these AI systems, fostering fruitful interactions and productive outcomes. The ongoing research process involves systematic experiments, thoroughly designed to ensure accurate and reliable results. By evaluating the flaws in the output and learning how to write prompts that effectively communicate with AI using natural language, this research strives to enhance the capabilities and limitations of text-to-image AI.

To recap, the research conducted comprises two significant experiments. The first experiment involved comparing the outputs generated by various text-to-image AI systems over a 12 months period (October 2022- October 2023), providing insights into the evolution and improvement of algorithms employed by these systems. The second experiment focused on different architectural scales, examining the accuracy of results when modifying the scale of the space. This investigation aims to understand the impact of scale on text-to-image AI systems and improve prompt writing methodologies for achieving desirable and replicable results.

Through these comprehensive sets of experiments, the research aims to contribute valuable insights into the evolution of text-to-image AI algorithms and the influence of architectural scales on generated outcomes. By enhancing prompt writing techniques and understanding the factors that contribute to reliable results, architects can leverage text-to-image AI systems more effectively in their design processes. This research opens up new possibilities for leveraging the power of AI in architectural visualization and pushes the boundaries of innovation in the field of text-to-image AI.

42 “The 10 Best Free Prompt Engineering Courses & Resources for ChatGPT, Midjourney & Co.,” medium.com, September 6, 2023.

Text-to-image Artificial Intelligence has the capacity to learn and generate accurate architectural plans, encompassing essential elements such as appropriate lineweight, spatial divisions, and even doors.

However, it is important to acknowledge that architecture and efficient design extend beyond technical aspects like producing a well-executed AutoCAD drawing or a blueprint.

In order to dive into a more comprehensive approach, the third chapter of this research raises inquiries about the subjective evaluation of “good” architecture. To explore this, sources such as books, online databases, insights from architects, and the expertise of architecture studios and professionals in the field are examined to discern the criteria that define the qualities of “good” or “bad” architecture. By analyzing and understanding these parameters, a deeper understanding of architectural excellence can be gained, going beyond the technical aspects and encompassing the artistic, functional, and contextual elements that contribute to the overall quality of architectural design.

3 Data, Parameters & Functions

To achieve success in leveraging the potential of this new technology, Architecture and Artificial Intelligence must work hand in hand, complementing each other's strengths and capabilities.

In the initial phase of the research, the primary focus was on gaining an understanding of the underlying logic behind how AI models generate images based on prompts. This involved studying the inner workings of AI algorithms, exploring their decision-making processes, and unraveling the mechanisms through which they interpret and transform text into visual representations. Simultaneously, there was a strong emphasis on mastering the art of effective communication with AI systems in order to generate the most accurate and desirable results. It is worth noting that the study of text and words has long been a part of architectural research[43], predating the emergence of AI.

Architecture, as a discipline, is inherently dynamic and evolutionary. Each project and space possesses its unique set of parameters that contribute to shaping its architectural form. Factors such as constraints, legal requirements, climatic considerations, user experience, cultural influences, and environmental aspects all play a role in influencing architectural design. The absence of identical projects reflects the understanding that architecture must respond to and accommodate the specific and diverse demands of its context.

43 Hadel Saad Al-Mur'ib Al, Ahmed A. Rashid Kbah, and Ibrahim Jawad Kadhim Al-Yousif, "Text Analysis in the Architect's Intention," JOURNAL OF XI'AN UNIVERSITY OF ARCHITECTURE & TECHNOLOGY XII, no. IV (2020) p. 1-16

This broader perspective allows for a comprehensive grasp of the multifaceted nature of architecture, recognizing its complexity and the multitude of factors that contribute to its success.

3.1 Evaluating Data Availability Source

The current landscape of AI systems, such as DALL E 2, relies on an online database as a primary source of information. These text-to-image AI models analyze a vast range of image and caption combinations sourced from publicly available sources on the internet, including websites, online platforms, image-sharing platforms and numerous others. By assimilating this diverse dataset, the algorithms adapt and refine their capabilities.

However, in the world of architecture, the situation differs significantly. Project blueprints, which form a crucial aspect of architectural design, are typically treated as confidential and rarely shared with the public. As a result, the online database of architectural plans, sections, and elevations either does not exist or lacks the comprehensive nature required for meaningful study and analysis within the field of architecture. This shortage of architectural data poses unique challenges in leveraging AI technologies effectively within the architectural domain.

Discovering suitable references in the field of architecture can be a complex task. It is crucial to acknowledge that architecture stands as one of the enduring disciplines with an extensive wealth of data accumulated over time.

To ensure comprehensive coverage, the references considered in this research are classified into four distinct categories. The first category comprises books that offer valuable insights, theories, and case studies related to architecture. These texts serve as foundational resources and contribute to a deeper understanding of architectural principles and practices.

The second category involves online archives, which provide a digital repository of architectural resources, including historical documents, drawings, photographs, and scholarly articles. These archives facilitate access to a vast array of architectural knowledge and serve as a valuable source of inspiration and information.

The third category encompasses professional practices within the field of architecture. This includes the work and expertise of established architects, architecture firms, and professionals actively engaged in architectural design and construction projects. Drawing upon their experiences and portfolios, these practices offer valuable real-world insights, innovative approaches, and successful case studies that contribute to the research.

The fourth category focuses on the work produced by students, specifically academic projects and research. Students' academics often explore novel concepts, innovative designs, and experimental approaches to architectural challenges. Incorporating student work into the research provides a fresh perspective and encourages exploration of emerging ideas and trends within the architectural realm.

By incorporating references from these diverse categories, the research seeks to draw from a wide range of sources, ensuring a comprehensive and well-rounded exploration of architectural concepts, theories, practices, and innovations.

3.1.1 Books: Neufert Architect's Data

One of the notable references explored in this section is the renowned book "Neufert Architect's Data". This influential publication serves as a valuable resource for understanding the complex aspects of architecture by breaking it down into smaller elements and pieces. With a logical and systematic approach, the book provides a comprehensive representation of architecture data that is classified and categorized for easy comprehension.

Within the pages of "Neufert Architect's Data," readers are guided through a wide range of architectural topics.

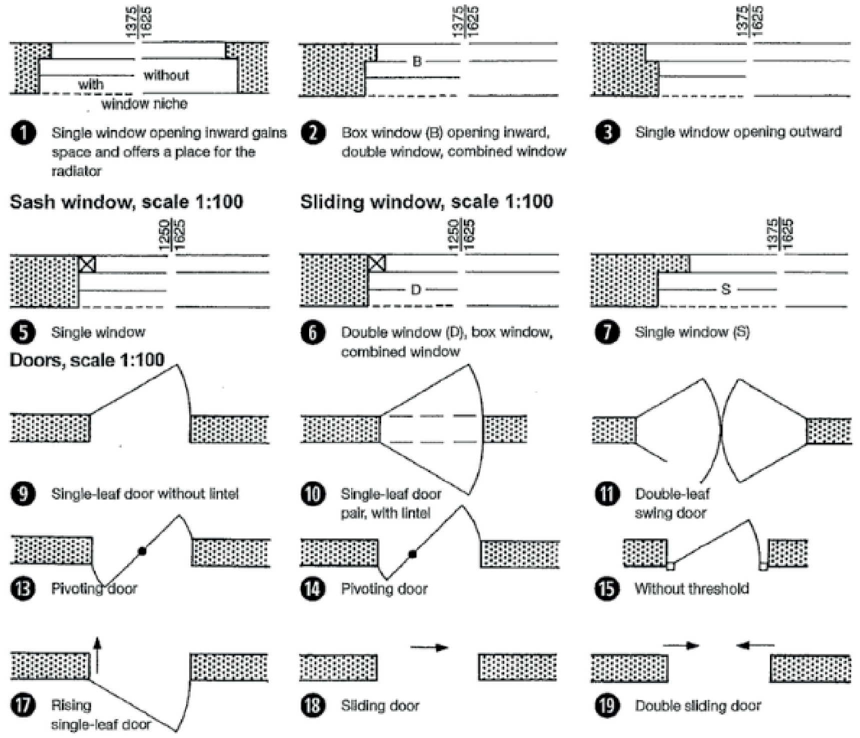

Figure 28: Preview of the content of the book "Neufert Architect's Data[44]" by Ernst and Peter Neufert

The book covers fundamental principles, building components, and the design process, offering valuable insights into the various stages of architectural creation. From conceptualization to construction, the book provides in-depth explanations, illustrative examples (shown in figure 28), and practical guidelines to aid architects in their design aspirations.

Furthermore, "Neufert Architect's Data" presents a comprehensive exploration of different types of spaces found in architecture. Whether it's residential, cultural, industrial, or other specific types of spaces, the book dives into the characteristics, considerations, and requirements associated with each category. By examining the diverse typologies of spaces, readers gain a deeper understanding of the unique challenges and opportunities presented by different architectural contexts.

The representation of architecture data in "Neufert Architect's Data" is precisely organized, ensuring clarity

44 Ernst Neufert and Peter Neufert, Architects' Data (Blackwell Science, 2000), p.23.

and accessibility for readers. With visually engaging illustrations and diagrams, the book effectively communicates complex architectural concepts, principles, and best practices. The logical structure and thoughtful categorization of information allow readers to navigate through the content seamlessly, enhancing their understanding of architectural design principles and processes.

“Neufert Architect’s Data” serves as a comprehensive and indispensable reference for architects and architecture enthusiasts alike. Its meticulous breakdown of architecture into smaller elements, logical representation of data, and exploration of various types of spaces make it an invaluable resource for gaining in-depth knowledge and insights into the multifaceted world of architecture.

This book serves as an invaluable resource for architects, providing them with essential knowledge that forms the foundation for comprehensive planning in any building project. Its primary objective is to streamline the architectural process by minimizing the time architects spend on extensive research.

The manual is a product of Neufert’s commitment to capturing key insights and identifying new opportunities in the field of architecture. It offers a personalized approach that delves into the elemental aspects of architecture, allowing architects to grasp essential principles and concepts efficiently.

However, it’s important to note that while the book provides a condensed source of valuable information, it does not encompass the entirety of architectural knowledge. Instead, it offers a focused perspective that emphasizes the fundamental elements of architecture. By presenting practical guidelines and proven methodologies, the book enables architects to establish a solid framework for their projects and streamline their workflow.

“Neufert Architect’s Data” equips architects with a wealth of information and techniques necessary for effective planning and design. It empowers them to navigate through the complexities of architectural projects with greater efficiency, informed decision-making, and a deep understanding of the fundamental principles that underpin successful architectural aspirations.

3.1.2 Online Databases
The Norman Foster Foundation Archive

The Norman Foster Foundation[45] was founded in 2015 with a clear objective: to protect and make known the remarkable architectural creations of Norman Foster.
As of now, the Foundation has an impressive collection of 116,302 papers in its Archive, including a wide range of materials such as blueprints, sketches, journals, models, photos, and personal items (numbers shown in the table below). This collection, which continues to grow, is an important resource of insights into Foster’s architectural genius.

To ensure the longevity and accessibility of these valuable resources, the Foundation engages in a three step procedure: conservation, organization, and digitization. Through careful conservation efforts, the Foundation ensures that each document is preserved and protected for future generations. The materials are carefully organized and cataloged (shown in figure 24), making it easier to find elements and thus facilitating comprehensive research for anyone interested in exploring Foster’s works. Moreover, the Foundation is committed to digitizing these materials, making them available online for a broader audience to explore and appreciate. This is part of making knowledge accessible for all the public.

The Foundation’s dedication to expanding the Archive is evident in the constant growth of its collection. As new documents and artifacts are acquired and added to the Archive, the understanding of Foster’s architectural legacy deepens. This ongoing expansion serves as a testament to the Foundation’s commitment to preserving and promoting Foster’s creations, ensuring that his architectural vision and contributions continue to inspire and educate individuals within and beyond the field of architecture.

45 “Archive — Norman Foster Foundation.” Norman Foster Foundation. https://normanfosterfoundation.org/archive/.

Plans	Sections	Elevation
1096	619	422

Table showing the Total of Plans, Sections and Elevations currently in the online archive (Last viewed on 01/06/2023).

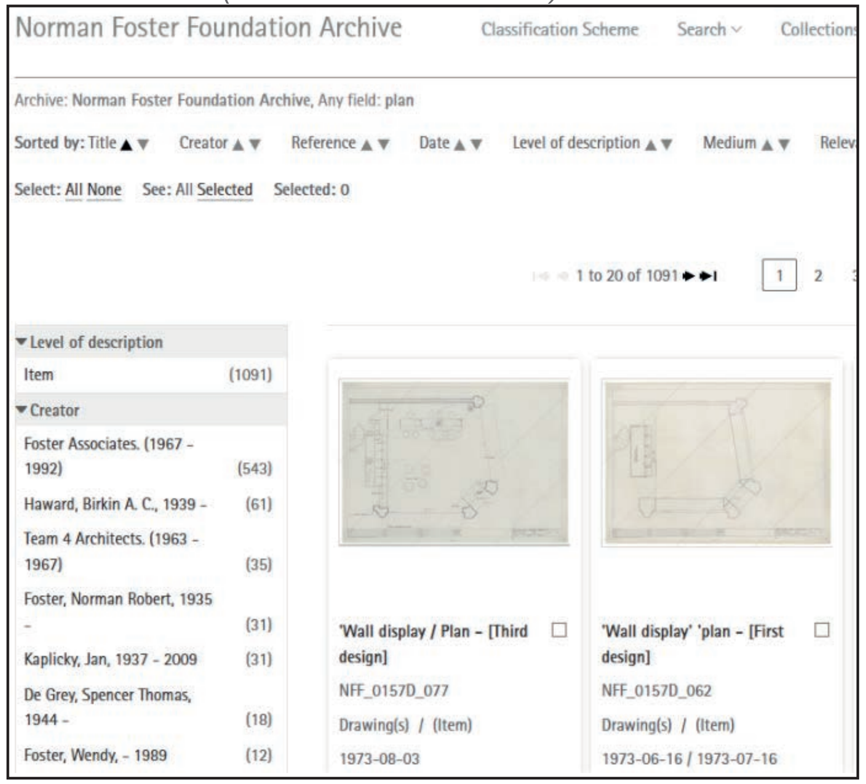

Figure 29: Preview of the Norman Foster Foundation Archive Search Bar[46]

The website of the Norman Foster Foundation Archive features a user-friendly search engine (shown in figure 29) that categorizes various architectural elements for easy exploration. Additionally, the collection is organized chronologically, allowing users to grasp the timeline of Norman Foster's career and observe his growth as an architect. This chronological system provides valuable context and helps users understand the historical development of Foster's work. Importantly, the data within the Archive is open to the public, meaning anyone can access and utilize it for research purposes.

This accessibility enables researchers, scholars, and enthusiasts to dive into Foster's architectural legacy and uncover valuable insights for their studies and projects.

46 "Norman Foster Foundation Archive." https://archive.normanfosterfoundation.org/en/consulta/resultados_ocr.do.

Conclusion

The Norman Foster Foundation holds significant importance in the world of architecture and its potential integration with future AI technologies, particularly in the field of text-to-image generation. By providing a comprehensive collection of architectural data and parameters, the Foundation offers a rich source of inspiration and reference material for AI systems to learn from and generate visual representations.

With its vast Archive comprising blueprints, sketches, models, and more, the Foundation equips AI models with a diverse range of architectural elements and design principles. This wealth of data enables AI algorithms to analyze, understand, and synthesize architectural concepts, styles, and features.

The Foundation's detailed organization and categorization, including chronological ordering, offer valuable context and a clear understanding of the evolution of architectural design over time.

Researchers and developers can exploit this data to train AI models in text-to-image generation, allowing them to produce visual representations based on textual input or descriptions. By utilizing the Foundation's resources, AI systems can potentially create realistic architectural renderings, aiding architects, designers, and urban planners in visualizing their ideas more effectively.

Ultimately, the Norman Foster Foundation Archive serves as an important repository of architectural knowledge and data, providing a solid foundation for future AI systems in the field of text-to-image generation. By using the public data that the Foundation has provided, AI technologies can contribute to the creative process, assist in design exploration, and advance the field of architecture in exciting and innovative ways.

President’s Medals:

In addition to the resources provided by the Norman Foster Foundation, another valuable reference source in the architectural domain is Presidents Medals[47], an accessible online database open to the public. This database showcases the projects of winning students, who submit their work under the guidance of their tutors.
By featuring these projects, Presidents Medals not only celebrates the achievements of talented students but also offers an in-depth glimpse into the current preoccupations and trends in architecture.

Each year, a select few winners are chosen from a vast pool of nominees representing various architecture schools. The winners then contribute their projects to the online database, further enriching its content. This continuous addition of student work, accompanied by the supervision of their tutors (number of entries shown in the graph of figure 30), ensures that the database remains up to date and reflects the evolving landscape of architectural education.

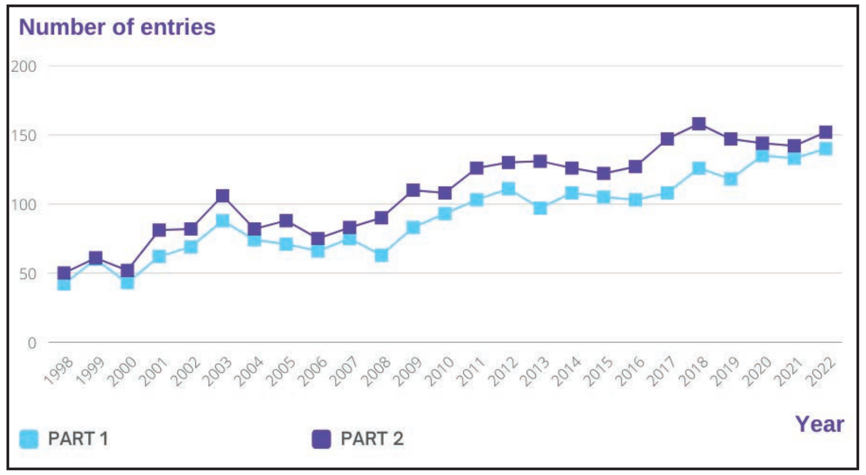

Figure 30: Line Chart of the Number of Entries Every Year Per Part (Source: Author)

Presidents Medals serves a dual purpose as an online architecture database. On one hand, it provides a platform for students to showcase their academic work, serving as an archive for their projects and preserving them for future reference. On the other hand, it acts as a knowledgeable curator by selecting the best works to feature, documenting these exceptional projects for wider recognition and study.

47 “The President’s Medals Student Awards.” ---The President’s Medals Student Awards. https://www.presidentsmedals.com/.

This dynamic online database of student projects not only serves as a source of inspiration for aspiring architects but also provides a comprehensive record of academic achievements and trends in the field. By including these projects in the database, it helps architects share knowledge, exchange ideas, and supports research in the field of architecture.

Conclusion:

Presidents Medals, for example, has a database of architectural projects that includes a wide variety of graphical representations without any set restrictions. Within this archive, one can find an array of graphical representations including diagrams, plans, sections, elevations, collages, renders, videos, and more.

The absence of specific formats allows for a creative and diverse collection of architectural documentation.

The freedom given to students and architects to choose their preferred format and medium of representation leads to a rich and varied architectural library. This diverse range of graphical representations not only showcases the creativity and individuality of each project but also presents a valuable opportunity for exploration and experimentation within the field of architecture.

Furthermore, this diverse collection of representational formats holds significant potential for training AI systems :

By exposing AI algorithms to a wide variety of architectural representations, including both traditional and unconventional formats, these systems can learn to understand and interpret different visual languages used in the discipline.

The availability of such a comprehensive database can serve as a solid foundation for training AI models to generate and interpret architectural visuals, enhancing the capabilities of AI systems in the context of architectural design and representation.

In summary, the absence of rigid formats and the presence of diverse representational mediums within architectural databases like Presidents Medals contribute to the development of a rich and varied architectural library. This, in turn, offers a valuable resource for training AI systems, enabling them to understand, interpret, and even generate architectural visuals with a broader range of formats and styles.

3.1.3 Professional Practices

In today's digital age, virtually every architecture studio has an online presence through websites. These websites serve as platforms to showcase the studio's work and demonstrate the quality of their designed spaces for potential clients.

In the 21st century, there is an abundance of knowledge available to learn about architecture. However, it is important to make careful choices when selecting reliable references or books to gain a comprehensive understanding of the complex world of architecture. With architecture having various aspects, this section explores diverse references to present a broader picture of the discipline.

The aim is to cover a wide range of perspectives and sources to ensure a more complete understanding of architecture. By exploring different references, architects and enthusiasts can expand their knowledge and develop a more well-rounded view of the field. This diverse exploration contributes to a richer architectural discourse and practice.

As an example, the website of BIG (Bjarke Ingels Group) showcases their projects categorized and organized as shown in figure 32.

It is quite fascinating to observe how each project is visually presented, accompanied by a slideshow and videos, effectively conveying the underlying idea behind it. The website of BIG (Bjarke Ingels Group) is designed with efficiency and directness, enabling researchers and users to save significant time when seeking information or inspiration.

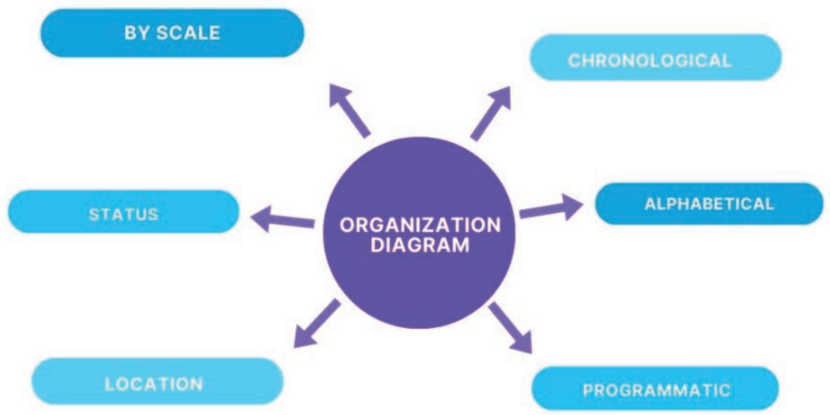

Figure 31: Diagram Showing the Organization Parameters Used by BIG for Their Projects (Source: Author)

Figure 32: Overview of the Interface of The BIG[48] Site and Project Organization Display

48 BIG | Bjarke Ingels Group. (n.d.). BIG | Bjarke Ingels Group. https://www.big.dk/

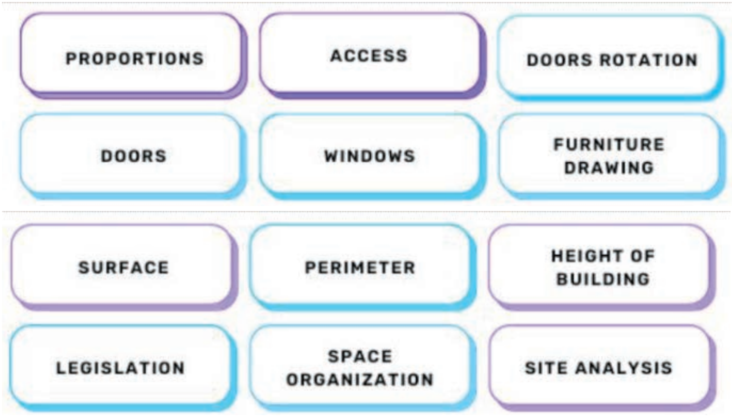

Figure 33: The Different Architecture Elements (Source: Author)

One can envision a practical organization of architectural information that adopts a similar sorting system. Artificial Intelligence (AI) has the potential to learn how to recognize cultural and architectural approaches specific to various locations. It can analyze patterns across different types of projects to develop an understanding of commercial aspects, among other factors. Furthermore, AI can familiarize itself with the diverse scales involved in various architectural projects.

Moreover, AI can also learn even the smallest architectural details, including proportions, access points, doors, windows, perimeter, and more, as shown in the figure 28 above. This extensive knowledge enables AI to provide valuable insights and assist in the creation of accurate and well-designed architectural projects. By understanding these fundamental elements, AI contributes to improving the precision and efficiency of architectural processes.

Defining reliable sources for architectural data is important. As explained in the previous section, there are numerous sources : Books, Online Archives, and Professional Practices. However, as we think further into trying to re-imagine architecture with text-to-image AI, it is important to understand the globality of the Architecture parameters. A project has to be the transcription of the written program / intention and demands of the clients.

3.2 Architecture Parameters

Architecture can be understood as a process of generating designs one can describe through two dimensions: on one side the diversity of the output produced or "Variety" and on the other side the applicability of the designs or "Relevance". [49]

When thinking about Architecture, Stanislas Chaillou expressed two dimensions that I think are important to discuss for this research. Part of the work of an Architect is actively making conscious and well educated choices in terms of variations of proposed project designs. Another important part is deciding whether or not the suggested designs are relevant to the program, the intention of the project and demands of the client. This part of the research sheds light on the Architect's role when presented with designs created through the assistance of the AI. It is an emphasis on the "communication" part with the tool.

Variety

The dimension of "Variety" in architecture is determined by two fundamental metrics: the "quantity of designs" and the "singularity of designs." The "quantity of designs" metric measures the volume of options created during the design process, reflecting the total number and range of design alternatives explored. On the other hand, the "singularity of designs" metric evaluates the level of distinctiveness among these design options. It quantifies the degree to which each design stands out from the others, taking into account their unique characteristics, features, and innovative elements. Together, these metrics contribute to the overall variety of architectural designs, capturing both the abundance of options and the diversity of their individual qualities. [50]

Relevance

"Relevance" in architecture is composed of two main aspects: "constructive feasibility" and "architectural quality."

Constructive feasibility refers to the practicality and workability of the designs. It considers factors like whether the design can be realistically built, the availability of

49 Stanislas Chaillou, "AI & Architecture, Towards a New Approach," Stanislas Chaillou | Architecture | Technology, p.21, http://stanislaschaillou.com/articles.html#pub-3-tag.
50 *Ibid*

materials, and the construction techniques involved. This aspect ensures that the proposed designs can actually be successfully brought to life.

Architectural quality, on the other hand, focuses on how well the designs meet certain standards. This includes factors like how well the different spaces are organized, how efficiently the layout utilizes the available space, and how well the design fits into its surrounding environment. It considers the functional requirements, user experience, and how harmoniously the design integrates with its context.

By considering both constructive feasibility and architectural quality, we ensure that the designs are not only practical but also meet high standards of functionality, aesthetics, and contextual suitability.

Conclusion:

This research highlights the importance of architects' active decision-making and their ability to balance variety and relevance in architectural design, including when working with AI-assisted tools. Architects must leverage their expertise to effectively navigate the multitude of design options available while ensuring that the designs remain relevant to the project's requirements and objectives. The integration of AI can enhance the exploration of design variations, but it is ultimately the architect's role to make informed choices and ensure the designs align with the program, intention, and client demands. By maintaining this equilibrium, architects can create designs that are both innovative and well-suited to their intended purpose.

3.3 Smart Assistant : Delegating Tasks to AI

The emergence of what I like to call "Smart Assistants" in the field of architecture has opened up new possibilities for delegating tasks to artificial intelligence (AI). These intelligent tools have the capability to handle various time-consuming and repetitive tasks, allowing architects to focus their energy on more creative and strategic aspects of their work. Smart Assistants can assist in tasks such as generating design options, analyzing data, simulating

environmental impacts, and conducting feasibility studies. By leveraging AI, Architects can enhance the efficiency of their work processes, increase productivity, and make informed decisions backed by data-driven insights. This symbiotic relationship between architects and Smart Assistants not only enhances efficiency but also encourages innovation and pushes the boundaries of architectural design. However, it is important to strike a balance and maintain human control, ensuring that the final design decisions are guided by the architect's expertise and vision.

3.3.1 Identifying Tasks of Efficient Design

In order to identify the different tasks an architect wishes to delegate to AI, we first need to understand how this "Smart Assistant" operates. As deduced from the previous section, data is available and abundant. The accumulation of knowledge online has now become a reality. However, when considering information, the concepts of sources and reliability also come to mind. As professionals navigating this digital era, we have developed online profiles or avatars that reflect our identities and interests. Consequently, we are continuously exposed to content and media that aligns with our research and ideas. For instance, if you are an architect, your social media platforms are likely filled with sketches, 3D images, and renderings. Even a simple search for "architecture" automatically directs relevant content towards your profile. This indicates that algorithms prioritize and deliver the most relatable content based on your search history. This is only an example of predictability related to the user. However, when discussing predictability in machine learning there is an important distinction to be made between two types of algorithms : regression algorithms & classification algorithms.
Although both algorithms help with the prediction process, the main difference is that :

Classification algorithms are used to predict and classify discrete values such as Male or Female, True or False, Spam or Not Spam, etc. (shown in figure 34)

Regression algorithms are used to predict and classify continuous values such as price, wage, age, etc. (shown in figure 35)

This predicts more or less what you look for. The reason why this is relevant to this research is: Architects have to understand that every generated output from AI is tailored to the user. This notion of predictability should always be in the back mind of the user. It will not only allow him to gain back control of his preferences but also give him an advantage when navigating / communicating with the “Smart Assistant”.

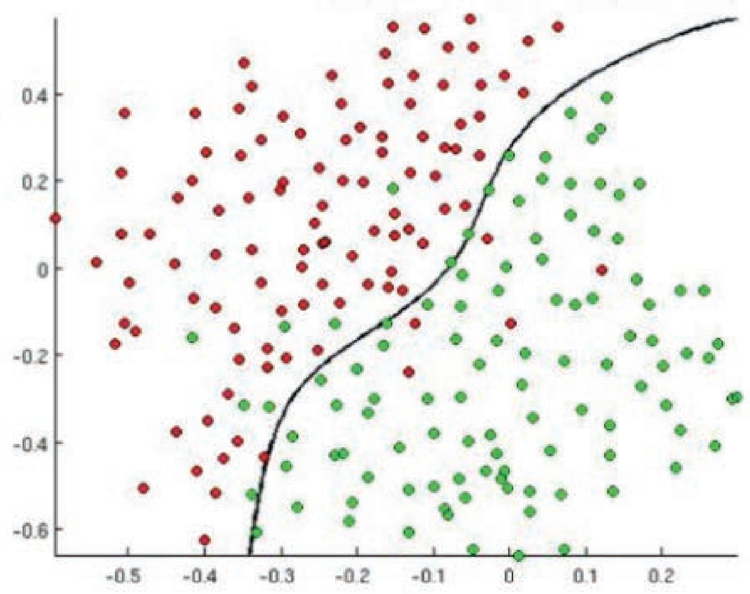

Figure 34 : Classification Graph[51]

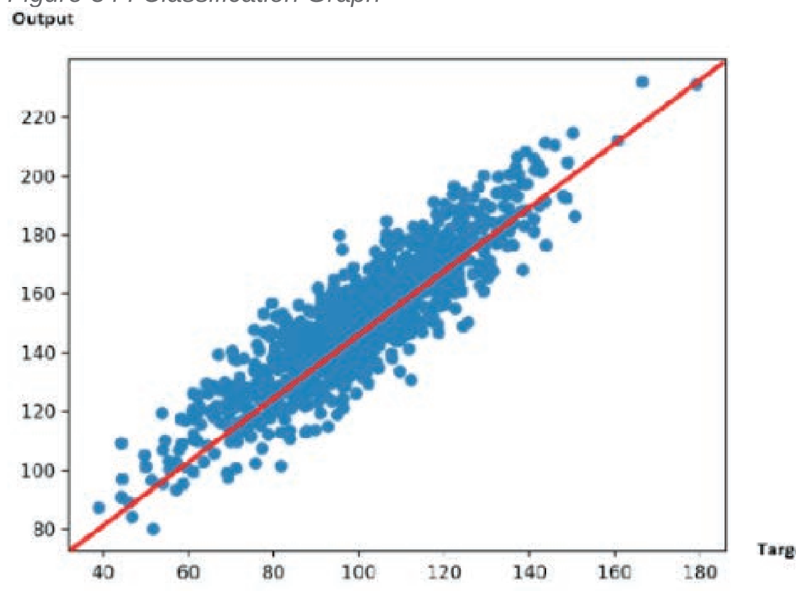

Figure 35 : Regression Graph[52]

It is important to note that AI has been a valuable tool in architectural design for many years, primarily employed for automation, optimization, and simulation purposes. It offers the ability to automate tasks that are repetitive or time-consuming, such as drafting, rendering, and documentation. Additionally, AI aids in optimizing design solutions by considering multiple criteria or constraints like cost, performance, sustainability, and aesthetics. Through simulation capabilities, AI enables architects to explore different scenarios and anticipate outcomes of design decisions, including analyzing structural behavior, energy consumption, and user experience.

51 “What is the Difference between Classification and Regression - The Genius Blog.” The Genius Blog. https://kindsonthegenius.com/blog/what-is-the-difference-between-classification-and-regression/.

52 Mohd Rizman Sultan Mohd, Juliana Johari, and Fazlina Ahmat Ruslan, “Conceptual Study of NNARX Method for Solar Radio Burst Prediction Model Development,” Journal of Electrical & Electronic Systems Research 18, no. APR2021 (2021): p.31–38, https://doi.org/10.24191/jeesr.v18i1.006.

“However, in recent years, AI has also been used in architectural design for more creative and generative purposes.”[53]

Therefore, we can imagine that architects can delegate far more tasks to AI, such as:

- generating design options (we have demonstrated in the chapter 2, that it is possible de use AI to generate design options using the right keywords),
- automating building information modeling (BIM),
- conducting environmental analysis, aiding material selection,
- checking code compliance,
- improving project scheduling and coordination efficiency, and enhancing virtual reality (VR) and augmented reality (AR) visualization.

By leveraging AI in these areas, architects can optimize their workflow efficiency, make data-driven decisions, improve project management, and enhance client communication and visualization.

Delegating these tasks to AI allows architects to focus on more strategic and creative aspects of their work, ultimately resulting in improved productivity and innovation in the field of architecture

3.3.2 Finding Functions to Assign to AI

From the previous part, we understand that AI can help the architect with a lot of the tasks, however, in this part, we’re doing a small prospective of scenarios where we actually

53 Iman Sheikhansari, “How AI Will Shape the Future of Architectural Design: A Critical Perspective on the Opportunities and Challenges of Artificial Intelligence,” LinkedIn, accessed June 8, 2023, https://www.linkedin.com/pulse/how-ai-shape-future-architectural-design-critical-iman-sheikhansari.

imagine using AI in the project and the conception.

There are two important conclusions to be made from the previous sections :
1. Architecture data is available.
2. Architects believe that human decision-making can complement computer generated suggestions.

However, the real question is : What are the functions to assign to AI?

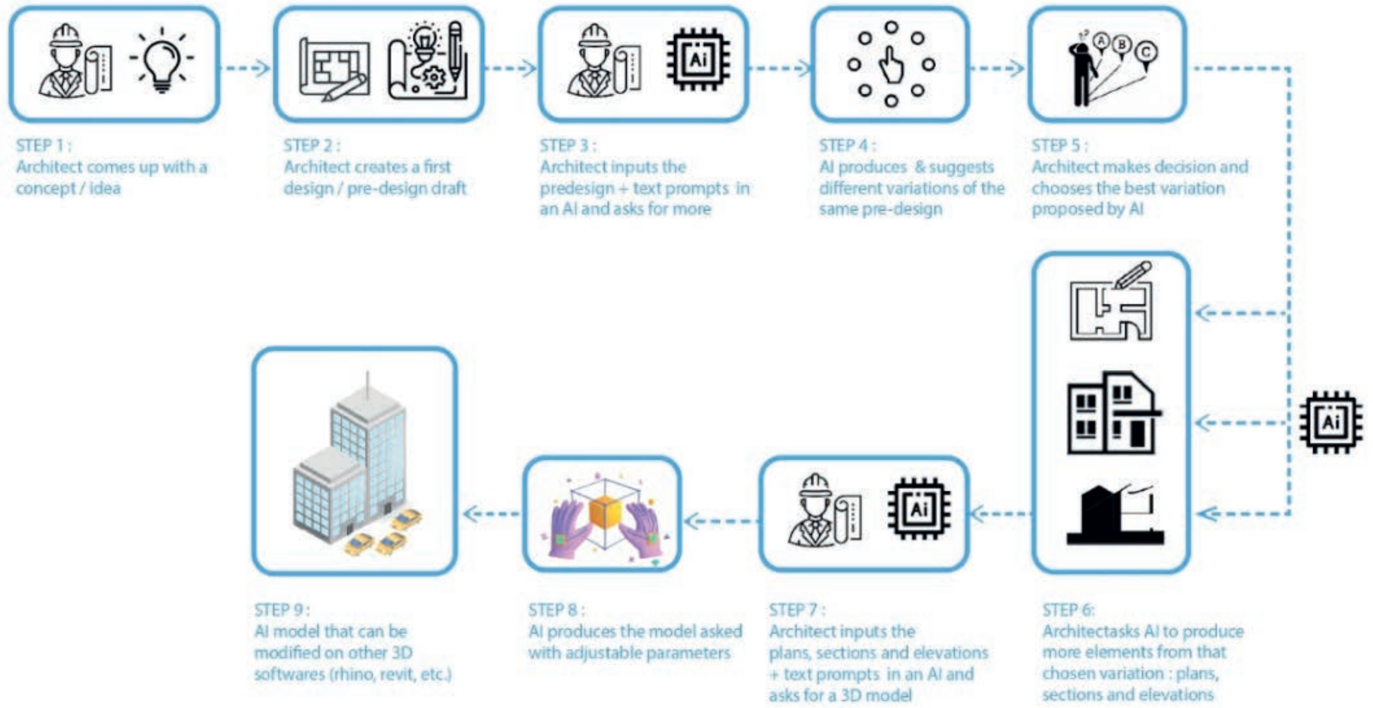

Figure 36 : Diagram presenting a potential scenario of the use of artificial intelligence in the design process (Source: Author)

We can imagine a scenario of an architect conceiving a project with the use of AI (shown in figure 36). For the sake of this scenario let's call our Architect : Bob.
Bob will start with an idea or a concept. He will conduct a site analysis, light study, and access study. Bob will also take into account proportions, spatial organization, user experience, etc. After this initial approach to the project called "l'esquisse" or the pre-design, the architect will draft a first proposition. This proposition would be the basis of what the architect will use to give tasks or instructions to AI. He'll ask AI to draft up a couple variations of the proposition. He can

then adjust some programs inside the space, some specific features and so on, to get a good result to work with.After choosing this best option generated by AI and the set of parameters that Bob gave (the different variables), he will then ask AI to create sections, plans and elevations of this option. After that, He can use the results of these elements and ask for a 3D model. The point is to use AI for its speed and variations creation, rather than let it create the whole space alone.

By going with this approach, errors by AI can be minimized, architects can supervise & make decisions when it comes to spatial organization, regulations, etc. Therefore, the main interest in this tool is to be able to use its neuron network that creates variations and possibilities to make the workflow faster when creating a project.

Conclusion of Chapter 3

In conclusion, this chapter has addressed several key aspects related to the integration of AI in architecture. Firstly, we have established that data resources are readily available and reliable, offering architects a wealth of information to inform their design processes. Secondly, we have examined the parameters of variety and relevance, highlighting their significance when collaborating with AI as a "Smart Assistant." Thirdly, we have identified numerous functions that can be effectively delegated to AI, aiming to harness its potential in assisting architects throughout their work. The constant evolution of technology continues to shape project approaches and various disciplines, including architecture. The emergence of AI has prompted a reevaluation of the design process itself and the potential future where professionals and academics embrace its inclusion.

The next and final chapter analyzes the process of conception, explores recent text-to-3D AI models and projects a vision into a future where architecture and AI work together to create a project.

4 Architectural Artificial Intelligence : A New Approach to Concept Design

With the growth of open data and the constant appearance of new projects worldwide, there has never been a better time to project the use of technology in architecture. As concluded in chapter 1, AI isn't trained with only architecture data. However, nowadays, projects are digitized and archived online. Therefore, now more than ever, technology can be introduced efficiently in the field of architecture. Artificial intelligence predicts what the user describes. It can adapt to new data, re-assess and give better results. This next chapter cuts down the concept process into different approaches to create parameters in the new AI tool for architects. We will also discuss the different ways of collecting data from architecture studios, as well, we will dive a little bit into text-to-3D and then finally create a prospective into the future of conception with the use of the new "Smart Assistant" (AI) in both the academic & the professional world.

4.1 The Process of Conception

There is no exact science when conceiving a project. Architects can get inspired by a number of things they do in the beginning to help them narrow down their imagination and focus on one idea or concept. Some architects base their initial concept on certain emotions, others get ideas by analyzing the site and its surrounding environment. Even some of them find inspiration in similar projects. The conception process is diverse and specific to the architect. However, there are a few general approaches to design when conceiving a project.

4.1.1 What is an Architectural Concept?

"Derived from the Latin verb concipere, a concept is about grasping or holding onto the real. Concepts are what allow us to apprehend reality. Conceptualizing a situation or event means extracting the potential of its circumstances. An architectural concept critically engages the circumstances, brief, and situation and formulates them in an original way."[54]

A concept is an idea, notion, or thought that serves as the organizing principle and inspiration for a design project, particularly one involving architecture. It becomes the driving force and focal point of a project's development and is routinely consulted at every step of its creation.

Architecture is a language. It is beyond the physical built space but rather an elaborate, ongoing integration of emotions, art, physics, sociology, aesthetics, cultural experiences, etc. Every designer develops their own architecture language. And with every project, and every architect, there is a different approach and design process. It all starts with one idea. It starts with a concept, an architectural concept.

As an example, Gilles Deleuze, Le Corbusier and Rem Koohlas have architecture concepts with respective theoretical perspectives to the architecture concept and design approach.

1. Gilles Deleuze:
Dynamic Becoming: Deleuze emphasizes the dynamic nature of concepts. He sees concepts not as static entities but as events in a state of continuous becomin: "Each concept is in a continual state of becoming". The concept of "becoming" is central to his philosophy, suggesting a fluid and transformative understanding of architecture.[55]

2. Le Corbusier:
Functionalism and Modernism: Le Corbusier's architectural concepts are often associated with functionalism and modernism. He advocated for the use of modern materials, open floor plans, and the idea that architecture should serve

54 Architecture concepts - UMass Amherst, 2017, https://www.umass.edu/larp/sites/default/files/Architecture%20Concepts.pdf, p.1-10.
55 Deleuze, Gilles, and Felix Guattari. What Is Philosophy? New York, Colombia Press, 1994.p19-22

the functional needs of its occupants. His “Five Points of Architecture” encapsulates some of these concepts, emphasizing elements like pilotis, free plan, and ribbon windows.[56]

3. Rem Koolhaas:
Rem Koolhaas, an avant-garde architect, crafts purposeful structures that challenge traditional norms. Rejecting a dedicated style, his designs emerge from meticulous research and a labor-intensive process. Koolhaas embraces ambiguity, providing spectators an open canvas for interpretation. His post-modern metabolic approach generates organic forms rooted in culture, fostering evolution within communities.

4.1.2 The Different Approaches to The Design Process

After deciding on a general concept, architects tend to focus on other aspects of the design process. They look into different approaches that will help them re-orient their initial abstract ideas into a clearer image of what the project might look like.

1. The concept begins to take shape when attributing a program to the space created. **This functional approach** helps with answering the requirements needed for a specific program and therefore narrows down the design options. Frank Lloyd Wright used to think of form and function as one. He designed environments that were functional and humane. By not only focusing on the aesthetic, Frank Lloyd Wright made sure that the space was functional and comfortable for the user. A very known example of this functional approach to architecture is “Falling Water[57]”. This project showcases how FLW wanted to create a home that was on with its surroundings.

2. Another important approach to the design is a **contextual approach** : Looking at the site analysis and surroundings, the historical elements of the place, and the people who occupy the area. Approaching the project from a historical, contextual point of view, allows for the people to remember what once was and revisit the story.

56 Le Corbusier.Vers une architecture. Paris: Les éditions G. Crès, 1923.
57 “Fallingwater - Frank Lloyd Wright Foundation.” Frank Lloyd Wright Foundation. https://franklloydwright.org/site/fallingwater/.

A very interesting example of this is “Beit Beirut”[58], located at the heart of Beirut, was once a residential building, is now a Museum and Urban Cultural Center. The revival of Beit Beirut relies on Preservation Adaptation and Reuse principles in its architectural design. All historical imprints spanning 92 years, reflecting time, war, and life since its 1924 construction, are preserved as poignant reminders, forming a “permanent museum collection.” The original structure is reinforced and adjusted to accommodate its new purpose.

3. We can also approach the design by starting to sketch. The first drafts and proportions attempt often lead to a more concretised idea of the space wanted. This formal approach where we take into account the drawing process and the study of scale, proportions and form is another way to develop the concept.

“I think of them as scribble,”
“I don’t think they mean anything to anybody except to me. At the end of the project we wheel out these little drawings and they’re uncannily like the finished building.”[59]

Located in the Bois de Boulogne, west of Paris, the Fondation Louis Vuitton stands as one of Gehry’s striking creations. While initially conceived as an abstract sketch, the finished building diverges from the single, ruffled entity in the drawing. Instead, it presents a more fragmented structure, with curved glass planes suspended over an angular, opaque volume. Despite this shift, Gehry’s dynamic lines persist, endowing the completed museum with the impression of a gleaming iceberg gracefully navigating through a sea of trees.

58 “Spent shell: Museum of Beit Beirut, Lebanon, renovated by Youssef Haidar - Architectural Review.”
59 “How Architecture Is Born: 7 Scribbles by Frank Gehry and the Buildings They Inspired - Architizer Journal.” Journal. https://architizer.com/blog/practice/tools/how-architecture-is-born-frank-gehry/.

Figure 37 : Image of Frank Gehry's Sketch of the Fondation Louis Vuitton

4. As well, architects are problem solvers and some of them approach design by studying and finding solutions to the site constraints. This constraints & solutions approach help shape the space and clarify the direction of the initial concept by solving existent site constraints.

In general, there are a lot of ways architects can approach the project. The previous approaches are merely a small part of how creative an architect can get when conceiving a new project. By projecting the profession into the future, we can imagine that AI could take on the pre-design step (or "l'esquisse") because it provides with a few words, an inspiration and an idea illustrated in images or in other words a concept. The next step would be for the architect to use the inspiration and start elaborating the design into a more tangible space. However, there are first a few things that AI needs in order to be used by architects : a reliable database.

4.2 Architecture Data Source

In order to establish a connection between AI and Architecture, it is crucial to acknowledge the diverse nature of the design process and the various approaches it surrounds. Furthermore, it is important to understand that AI requires training using a comprehensive database to generate the desired results. As discussed in the previous chapter, architecture data is indeed available. However, it is worth noting that certain prominent architecture studios, known for their extensive and high-quality designs, may not necessarily share their projects online or with the public. This limited accessibility to their work poses a challenge in terms of obtaining a sufficiently diverse and representative dataset for training AI models in the field of architecture.

There are a few ways to gather architectural data:

1. **Asking for Cooperation**: We can reach out to architecture studios and request that they share their work. This collaboration would involve using the data once the new AI tool or technology is fully developed.
2. **Buying Data**: Another option is to purchase architectural data directly from studios. This data can be used to train AI models to create similar spaces or projects based on existing designs.
3. **Using Open Source Data**: We can also make use of freely available architectural data that has been shared online. Although this data may have some missing information, we can try to fill in the gaps and supplement it to create a more complete dataset for AI training.

Each option has its own advantages and challenges, and the decision depends on factors such as data availability, willingness of architecture studios to collaborate, and project resources and goals.

No matter how we gather architectural data, it is crucial to exercise caution, particularly in the language and information AI receives as text prompts and uses as a database. AI is a machine capable of learning anything, which means that if we intend for this new tool to be useful for architects or architectural students, it must be carefully monitored and filtered by architects and international professionals in the field. This oversight is necessary to ensure that the tool is reliable and aligns with the standards and expertise of the architectural community.

4.3 AI Adapted Model : text-to-building

The repetitive aspects of the architecture profession can be minimized to give more time for the creative aspect. Architects can automate some of the less appealing tasks and still be able to make decisions when it comes to the search for logic and sense of space.

Text-to-image AI can become text-to-BIM AI or even sketch-to-building AI. In a way, as a younger architect that has still not built much in the world, the profession of architecture can be augmented to exponential results that were not possible due to the lack of data and openness to technology. The profession can be made not to be easier but a lot more efficient and optimized. The goal is to be able to train existent AI systems and include more parameters with the prompt.

The development of diffusion models[60] for generative image modeling has led to significant progress in creating images based on text prompts. This progress is primarily driven by the availability of powerful computers and large databases containing billions of samples, which include images with associated text gathered from the internet, like social media platforms and search engines such as Google and Pinterest. On the other hand, progress in creating 3D content has been slower. However, the limitations encountered in concepts like text-to-3D open up new possibilities for other researchers and scientists in the field to explore. In the following sections, we will discuss the latest advancements in AI, specifically focusing on text-to-3D technologies developed by DreamFusion and NVIDIA.

This part of the research provides a glimpse into how architects can reimagine AI as an assistant and explores the inevitable changes and evolution of architectural conception. It sheds light on the potential transformation of the architectural field through the integration of AI technologies and its impact on the way architects conceive and develop their designs.

4.3.1 Text-to-3D : DreamFusion & Magic3D

DreamFusion: Text-to-3D using 2D fusion

Release date : September 2022

60 Ryan Connor, "Introduction to Diffusion Models for Machine Learning," News, Tutorials, AI Research, April 19, 2023, https://www.assemblyai.com/blog/diffusion-models-for-machine-learning-introduction/.

Figure 38 : Examples of text-to-3D by DreamFusion

As mentioned before, there have been recent advances in text-to-image AI. Part of the success in the image generation process is the dataset behind it: billions of text-to-image pairs found online and trained by diffusion models. However, the approach to text-to-3D, had to be different because of numerous limitations such as : there are no large-scale datasets of 3D data online as there are for images.

Therefore, DreamFusion approached text-to-3D differently (figure 38). They decided to create textured 3D models from text with no 3D training. In other words, to surpass the limitation of having no 3D data, they use their existing text-to-2D-image diffusion model (pre-trained images used as prior), along with Neural Radiance Fields (NeRF)[61].

The algorithm behind NeRF uses a fully-connected (non-convolutional) deep network to represent a scene. The input to the deep network is a single continuous 5D coordinate (spatial location (x, y, z) and viewing direction (,)), and the output is the volume density and view-dependent emitted radiance at that spatial location (figure 39).[62]

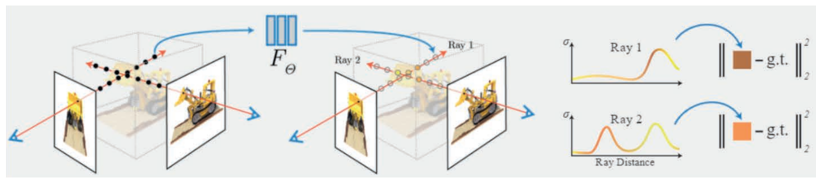

Figure 39: NeRF system Overview

NeRF basically creates a random scene (surrounding, lighting, shading) using the different images as input. It shows the 3D object from angles never seen before. It recovers the geometry of a specific scene. However, this study demonstrated that pre-trained 2D image-text models can be used for 3D synthesis, though the 3D objects produced by this method lack realism and accuracy. The following shows

61 Ben Mildenhall, Pratul P. Srinivasan, Matthew Tancik, Jonathan T. Barron, Ravi Ramamoorthi, and Ren Ng. Nerf: Representing scenes as neural radiance fields for view synthesis. In ECCV, 2020.
62 "NeRF: Neural Radiance Fields." Matthew Tancik. https://www.matthew-tancik.com/nerf.

an example of the approach to text-to-3D.

DreamFusion optimizes a 3D scene based on a caption using the Imagen[63] (google's diffusion model) text-to-image generative model. They suggest Score Distillation Sampling[64] (SDS), which involves optimizing a loss function to produce samples from a diffusion model (it is the process of generating high quality samples with fewer steps, making the process faster, and thus saving time).

As long as they can map back to images differently, SDS enables them to optimize samples in any parameter space, such as a 3D space. To define this differentiable mapping, they employ a 3D scene parameterization that is similar to Neural Radiance Fields, or NeRFs. SDS alone creates an acceptable scene appearance, but DreamFusion enhances geometry with extra regularizers and optimization techniques. The trained NeRFs that are produced are coherent, have excellent normals, surface geometry, and depth, and can be relit using a Lambertian shading model[65].

As discussed, DreamFusion encountered limitations when developing their text-to-3D model, therefore the next part is the work of Nvidia called Magic3D and a comparison of both models.

NVIDIA : Magic3D
Release date : November 2022

Figure 40: Example of text-to-3D generated by Nvidia "Leaning tower of Pisa"

Magic3D, developed by Nvidia, focuses on learning from DreamFusion and working on their limitations.

63 "Imagen: Text-to-Image Diffusion Models." Imagen: Text-to-Image Diffusion Models. https://imagen.research.google/.
64 Salimans, Tim, and Jonathan Ho. "PROGRESSIVE DISTILLATION FOR FAST SAMPLING OF DIFFUSION MODELS." p1-21, 2022.
65 "Introduction to Shading (Diffuse and Lambertian Shading)." Scratchapixel. https://www.scratchapixel.com/lessons/3d-basic-rendering/introduction-to-shading/diffuse-lambertian-shading.

The disadvantage as seen above is mostly based on the lack of diverse, large-scale 3D datasets; 3D content is much harder to find online than image and video content. As well, the resulting 3D content generated by DreamFusion lacked good quality and took a lot of computing time.

The difference with Nvidia is that it presents a method for generating highly detailed 3D models from text prompts in a short amount of time (figure 35). They propose a "coarse-to-fine" optimization approach that optimizes the 3D representation using multiple diffusion priors at different resolutions, allowing the generation of both view-consistent geometry and high-resolution details. Magic3D can produce high-quality 3D mesh models with greater resolution in 40 minutes, which is two times faster than DreamFusion (which apparently takes 1.5 hours on average).

The way it works

Nvidia generates high-resolution 3D content in a coarse-to-fine fashion from an input text prompt. To obtain the coarse (harsh or rough) model, they use a low-resolution diffusion prior and optimize neural field representations (color, density, and normal fields) in the first stage. Then they extract textured 3D mesh from the coarse model's density and color fields. ANd they use a high-resolution latent diffusion model to fine-tune it. Their model generates high-quality 3D meshes with detailed textures after optimization.

4.3.2 Key Differences Between Magic3D & DreamFusion

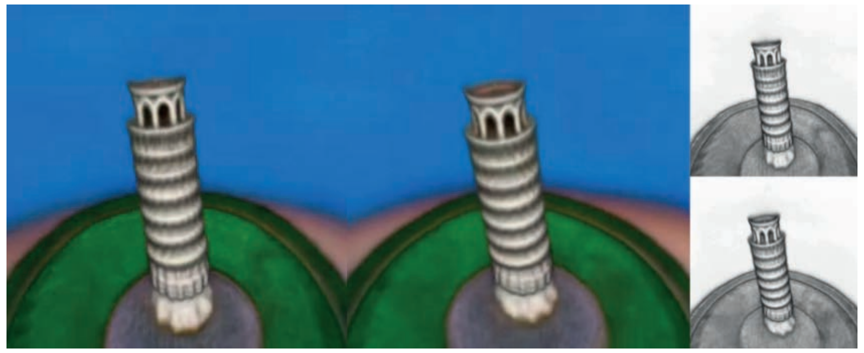

Figure 41 : Example of text-to-3D generated by Dreamfusion "Leaning tower of Pisa" (compare with figure 40)

The difference between the text-to-3d model developed by

DreamFusion and the Nvidia Magic3D model is summarized in this next part (shown in figures 40 & 41).

1- Coarse-to-fine Diffusion Priors
In the first stage, to generate high-resolution geometry and textures, Magic3D employs two different diffusion priors in a coarse-to-fine fashion. In the first stage, they use the eDiff-I [66] base diffusion model, which is similar to the Imagen base diffusion model[67] used in DreamFusion.

In the second stage, they use the latent diffusion model (LDM) , which allows backpropagating gradients into rendered images with a high resolution of 512x512; in practice, they use the publicly available Stable Diffusion model.

2- Scene Models
To support the higher resolution of rendered images for the input of high-resolution priors, they adapt two different 3D scene representations to the two different diffusion priors at coarse and fine resolutions, as discussed below.
They use an encoding system that allows a higher representation of details at a lower computational cost
They use textured 3D meshes as the scene representation. Unlike volume rendering for neural fields, rendering textured meshes with differentiable rasterization can be done efficiently at very high resolutions, making meshes a decent fit for their high-resolution optimization stage.

Extensive user research and qualitative comparisons show that Magic3D is preferred by raters (61.7%) over DreamFusion, despite a 2 speed increase. Magic3D also proposes a set of tools for improving style and content control in 3D generation.

The presence of these recent tools (text-to-3D models) represent only the beginning in the world of technology. Therefore, as AI models start becoming more common, architects need to start projecting how they will use these tools in the foreseeable future.

The main question for architects is : What will be the future of architecture conception?

66 Yogesh Balaji, Seungjun Nah, Xun Huang, Arash Vahdat, Jiaming Song, Karsten Kreis, Miika Aittala, Timo Aila, Samuli Laine, Bryan Catanzaro, et al. ediff-i: Text-to-image diffusion models with an ensemble of expert denoisers. arXiv preprint arXiv:2211.01324, p.1-20, 2022.
67 Robin Rombach, Andreas Blattmann, Dominik Lorenz, Patrick Esser, and Björn Ommer. High-resolution image synthesis with latent diffusion models. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), p.1-8, June 2022.

4.4 The Future of Architecture Conception

The approach to architecture has never been linear. With the constant variables and change in time, architects have always adapted their approach to space by taking into account the needs of the user among other factors. With the digital age, architects as well as any other professionals have found themselves immersed in Big Data.
Like never before, data is abundant and stored. It can be studied, analyzed and learned at an immense scale with great rapidity. The interest of this paper revolves around speculating the efficient use of existing tools to optimize the design process in terms of time efficiency and creativity.

Text-to-image AI systems have shown to be a source of knowledge for any one. From words, there are endless possibilities of inspiration and creativity. As architects, expressing ideas graphically has always been a long process. Now we can imagine introducing text-to-image AI in the pre-design all the way to the construction phase.

With a few words of a potential idea an architect has, text-to-image AI can generate images that can be used as inspiration as a first approach. Then, architects can use the inspiration images to start drafting. The initial draft can be used as an input or prompt and generate more variations. Again, the architect makes conscious choices and decides on a variation of the initial draft. After that, we can imagine taking in more views and details when it comes to the chosen variation as well as asking AI to produce sections and elevations of the plan.

As a third step, we can input the images of the plan, sections and elevations to an AI that generates 3D models. We can imagine a new cycle or approach to the design process based on optimizing time and improving the quality of the space.

Prospective

AI has the potential to greatly assist architects throughout the various phases of a project (shown in the figure 37).
In the concept development phase, as seen in the experiments conducted above, AI can aid architects in design exploration by generating a multitude of design options based

on specified criteria and constraints. Additionally, AI-powered generative design algorithms can propose innovative and optimized design solutions by analyzing large datasets and identifying patterns. We can then imagine having

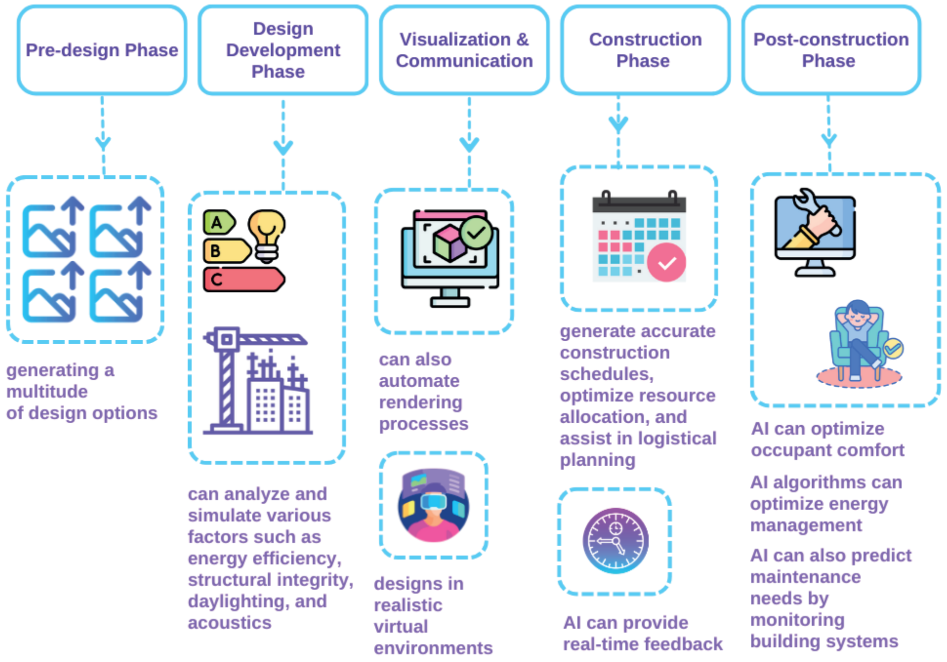

Figure 42 : Graphic Displaying a Summary of The Different Potential Roles of AI in the Different Phases of a Project (Source: Author)

parametric design tools powered by AI to be able to automate the generation of design variations based on parameters (as expressed in the chapter 3 of this research), enabling architects to quickly test and generate designs, leading to more creative and informed decision-making.

During the design development phase, AI can play a crucial role in optimizing performance. AI algorithms can analyze and simulate various factors such as energy efficiency, structural integrity, daylighting, and acoustics. We can take the example of Autodesk Forma[68] (formerly Spacemaker), a tool that helps planning and design teams work digitally from the beginning of a project. It offers conceptual design capabilities, predictive analytics, and automations to create a solid foundation for your projects. It helps to make informed and smart design decisions in real-time by leveraging data-driven insights, reducing risks, and improving business and sustainability outcomes.

68 "Autodesk Forma Software (Formerly Spacemaker): Login & Buy Forma," Autodesk Forma Software (formerly Spacemaker) | Login & Buy Forma, May 15, 2023, Accessed 6 June 2023 https://www.autodesk.com/products/forma/overview?term=1-YEAR&tab=subscription.

This analysis can provide architects with valuable insights and suggestions for design modifications that enhance the performance of the building. AI can also assist in computational modeling by automating the creation of detailed and accurate 3D models, saving time and effort in the design process. Furthermore, AI can provide recommendations for suitable materials based on desired performance criteria, cost, and sustainability goals, assisting architects in making informed material selections.

In terms of visualization and communication, AI-powered tools offer exciting possibilities. Virtual and augmented reality experiences generated by AI can provide immersive visualizations that allow architects and stakeholders to experience and understand designs in realistic virtual environments. This enables better spatial comprehension and can facilitate effective communication and decision-making. AI can also automate rendering processes, generating high-quality visual representations of architectural designs, saving time and resources in the visualization process. Additionally, through natural language processing, AI can help architects communicate design ideas more efficiently by converting spoken or written descriptions into visual representations (with text-to-image AI for example), aiding in effective collaboration with clients and colleagues.

Moving into the construction and project management phase, AI can expedite processes and improve efficiency. AI algorithms can generate accurate construction schedules, optimize resource allocation, and assist in logistical planning.

This can lead to :
1. *improved project timelines,*
2. *cost-effectiveness,*
3. *and reduced risk of delays.*

AI can also contribute to quality control by monitoring construction progress and comparing it to design specifications. In case of deviations or potential issues:

AI can provide real-time feedback, enabling architects to address them promptly.

AI-powered systems can analyze construction site data to identify potential safety risks and suggest preventive measures, enhancing overall construction safety.

Even after construction, AI continues to be valuable in the post-construction and performance monitoring phase:

AI can optimize occupant comfort by analyzing sensor data related to factors such as indoor air quality, thermal comfort, and lighting, and providing feedback for adjustments that improve the well-being of building occupants.
AI algorithms can optimize energy management by analyzing energy usage patterns and suggesting strategies to reduce consumption, leading to increased sustainability and cost savings.
AI can also predict maintenance needs by monitoring building systems, enabling architects to implement proactive and predictive maintenance practices to ensure the long-term durability and efficiency of the building.

To sum up, the collaboration between architects and AI holds tremendous potential to enhance architectural conception and revolutionize the entire project lifecycle. By leveraging AI's capabilities in design exploration, performance optimization, visualization, construction management, and post-construction monitoring, architects can create more efficient, sustainable, and engaging designs that positively impact the built environment.

Conclusion

In this exploration of the interaction between Architecture and Artificial Intelligence (AI) within the era of Big Data, the central question posed was:

How can architects use text-to-image AI to increase creativity and improve design?

The hypothesis suggested that architects could use AI algorithms to elevate architectural design, creating more effective, efficient, and sustainable solutions. Furthermore, the study examined the potential of generative AI in generating diverse design options and optimizing solutions. The focus extended to the pre-design phase, emphasizing the prevention of issues and the verification of design feasibility through AI's advanced simulations and predictive modelling. The results emphasize architects' crucial role in decision-making and the significance of acquiring prompt-writing skills. The research offers practical methods for architects to enhance their utilization of AI tools, providing valuable insights into the changing dynamics of AI in architectural design.

The research first serves as a foundational exploration of Architectural Artificial Intelligence, charting its evolution and emphasizing the significance of Generative AI. Architects benefit by generating diverse options and optimizing solutions efficiently, enabling exploration of a broader design spectrum in less time. It highlights the integration of algorithms in pre-design, preventing issues through advanced simulations, and allowing feasibility verification before physical realization.
The experimental part of the paper delved into evaluating the flaws in AI outputs and emphasized the pivotal role of effective prompt writing for architects. Findings from the first experiment highlighted the rapid training potential of AI, the significant role architects play in decision-making, and the importance of prompt writing for improved results.

The research then explored the richness of data resources available to architects, offering valuable information for design processes. Two crucial dimensions in generated AI images were identified: variety and relevance. Architects were found to balance these aspects, ensuring innovative and project-aligned designs through expertise-driven decision-making. And finally, the dissertation investigated different approaches in the concept process, allowing architects to create new parameters for AI. It highlighted the potential for architects to automate less appealing tasks while retaining decision-making authority in logic and spatial sense searches.

While the study demonstrated the immense potential of AI in enhancing architectural design, certain challenges emerged. The delicate balance between variety and relevance required perceptive decision-making from architects to align AI-generated designs with project requirements. Additionally, the reliance on AI raised questions about potential overreliance, emphasizing the importance of maintaining a symbiotic relationship where architects remain the driving force behind creative decisions.

In addition to the outlined benefits, it is crucial to emphasize the importance of critically evaluating the sources and reliability of the data feeding AI algorithms. As AI becomes an integral part of architectural processes, ensuring the accuracy and trustworthiness of the data is paramount for informed decision-making.
Moreover, the discussion extends to the integration of AI in academia and architectural practices. Establishing effective methodologies for incorporating AI into educational curricula equips future architects with the skills to harness AI's potential. Simultaneously, the seamless integration of AI into professional practices requires thoughtful consideration of ethical implications, user training, and ongoing collaboration between architects and AI systems

Future research in the world of Architectural Artificial Intelligence can extend its focus on various crucial dimensions. Investigating the continuous advancements in AI algorithms is imperative to understand their evolving impact on architectural outcomes over time. The development of methodologies in prompt writing deserves continued attention to enhance the nuanced interaction between architects and AI systems. Ethical considerations and potential risks tied to increased AI integration in architectural processes necessitate comprehensive exploration, covering privacy concerns and the ethical responsibilities of architects. Examining human-AI collaboration in design processes will shed light on how architects can seamlessly integrate AI as a creative partner while preserving the uniqueness of human intuition. Furthermore, exploring strategies for incorporating AI education into architectural curricula is essential to equip future architects with the skills to navigate the symbiotic relationship between human creativity and machine intelligence. Investigating the long-term impact of AI on architectural design trends, considering aesthetic preferences and spatial configurations, provides insights into the evolving architectural language. Lastly, studying user experience and acceptance of AI-generated designs is crucial for understanding user preferences, adaptability, and the role of AI in meeting client expectations. These avenues collectively contribute to advancing our understanding of the multifaceted integration of AI in architectural practices and education.

In conclusion, this study offers valuable insights into the dynamic integration of AI in architectural design, highlighting the collaborative potential between architects and AI. The findings accentuate architects' pivotal role as decision-makers in harnessing the diverse possibilities presented by AI tools. Future research should delve deeper into emerging AI technologies, exploring ethical considerations and strategies for a harmonious collaboration between architects and AI, shaping the future of architectural design. Further investigations can explore how architects might develop specialized AI tailored exclusively for architectural purposes, contemplating the creation of dedicated AI tools. Another avenue involves the integration of AI through plug-ins in existing architectural software like Revit, a method that can streamline AI utilization in established design workflows.

Additionally, future research may focus on the experimentation and testing of parameters to be incorporated into AI systems for architects, ensuring optimal customization and efficacy in addressing the unique challenges of architectural design processes. These research directions collectively contribute to advancing the symbiotic relationship between architects and AI in the evolving landscape of architectural practice.

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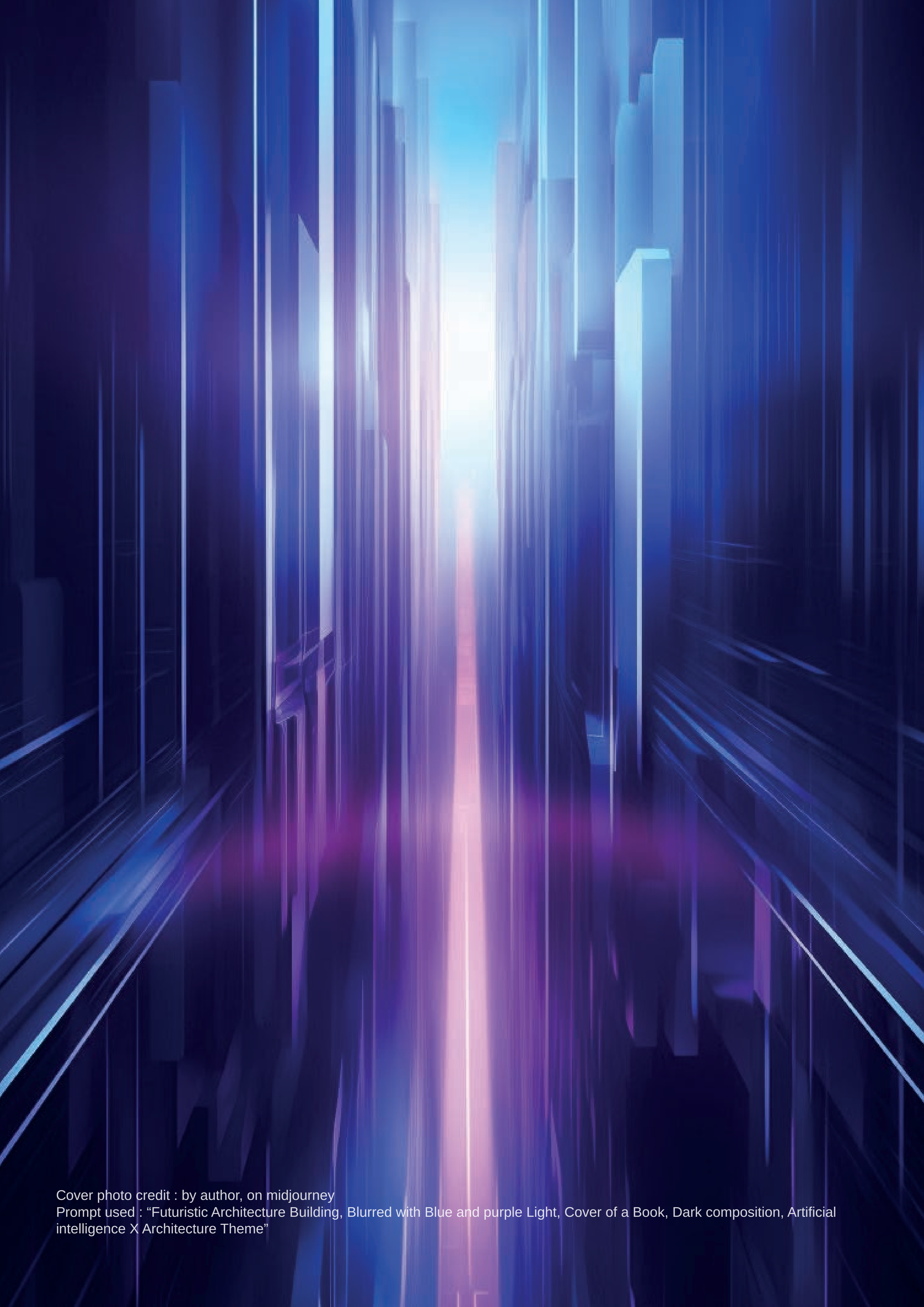

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Prompt used : “Futuristic Architecture Building, Blurred with Blue and purple Light, Cover of a Book, Dark composition, Artificial intelligence X Architecture Theme”